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A BRIEF LIST OF WORKS ON METEOROLOGY

Compiled by RICHMOND T. ZOCH

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THE DETERMINATION OF EVAPORATION FROM LAND AND WATER SURFACES

By C. W. THORNTHWAITE and BENJAMIN HOLZMAN

[Soil Conservation Service, Washington, D. C., February 1939]

The problem of determining rate and amount of evaporation from land and water surfaces, or transpiration from vegetation, is rendered complex by the fact that the water becomes an invisible gas which rapidly mixes with the other gases of the atmosphere and is transported large distances and to great heights. A method for the accurate determination of water losses from lakes and reservoirs is of vital importance, but it is equally important to determine water losses from watersheds and from agricultural lands.

It is not possible to determine actual transpiration or evaporation from either free water surfaces or land surfaces by simply measuring the rate of loss of water from an exposed pan or atmometer. The amount of transpiration for any plant type is partly a function of leaf area, which varies seasonally with the growth cycle of the plant. Transpiration also varies from one plant species to another, depending on water requirements, the osmotic value in the leaves, and the number, nature, and size of the stomata. None of these factors is reflected by pan or atmometer measurements of evaporation.

Neither do these measurements indicate the evaporation from the soil. When the surface soil is moist the evaporation exceeds pan measurements because the soil with its minute irregularities presents a greater evaporating surface and because surface soil temperatures during the part of the day when most of the evaporation occurs are higher than water temperatures. When, however, the surface soil has become dry or partially dry, less evaporation occurs from the soil than from a pan. Even though the subsoil is moist, capillary action cannot supply the surface with water at a rate at all comparable to the evaporation from the surface of a body of water. Hence, water molecules can escape to the outer air only by a very slow diffusion process which takes place from the lower soil levels through the soil air, and results in a deceleration in the rate of moisture loss.

Since the rate of emission of water vapor from a land, water, or plant surface cannot be measured directly as can the rate of water accretion to the surface and since the measured rate from a pan or atmometer cannot give this rate of emission, the evaporation problem must be approached in a different manner.

Observations of evaporation from lakes, reservoirs, and pans have been used in the development of many empirical formulae in which evaporation is expressed as a function of various meteorological data such as temperature, relative humidity, barometric pressure, wind velocity, and solar radiation. Dalton (5) was the first to point out that evaporation is proportional to the difference between vapor pressure of the air at the water surface and that of the overlying air, although apparently he never expressed this relationship in mathematical terms.

In Rohwer's "Evaporation from Free Water Surfaces," published in 1931, (20) a number of evaporation formulae are presented and discussed. Most of these formulae contain the expression (e_s-e_d), e_s being the vapor pressure at the surface of the liquid and e_d the vapor pressure of the air, and a factor W expressing the influence of wind velocity. Rohwer's empirical formula is:

$$E=(0.44+0.118W)\ (e_s-e_d)$$

which, he says, is of the same form as Dalton's original formula:

$$E=C(e_s-e_d).$$

A different approach to the problem of determining evaporation from lakes and other bodies of water has been suggested by Ångström (2). He indicated that there must be a balance of energy between the insolation absorbed by a body of water and the energy exchanges due to radiation, convection, conduction, and the latent heat of evaporation, and that evaporation might be determined by measuring the necessary components of this equilibrium. Richardson (18, 19) and Cummings (4) have used this principle in determining evaporation losses but difficulties in obtaining various essential measurements, such as temperature gradients within the body of water and heat exchanges due to convection, prevent the determination of accurate short time measures of evaporation and prohibit the determination of moisture losses from land areas. Yamamoto (39) has made similar use of the conservation of energy principle in his studies of condensation of dew.

In recent years advances in aviation have stimulated the study of the structure of the lower atmosphere from which has come much essential information on turbulence and the intensity of turbulent mixing. In the free air there is a zone above the earth's surface in which the frictional effects of the ground are felt. This is the zone of turbulent mixing, or the turbulent layer. In this layer the mixing process is very important and depends on the shearing stresses associated with the roughness of the ground and with the wind structure, the thickness of the layer increasing as the value of these factors increases. The mixing process also depends upon the stability or density structure of the air, the mixing diminishing as stability increases. Beneath the turbulent layer there is a shallow layer usually measured in millimeters, called the laminar layer, in which air flow is laminar, where mixing proceeds by diffusion only. The vertical motion of the air in the turbulent layer tends to establish an adiabatic distribution of properties of the air, and thus to eliminate differences in moisture concentration. If moisture is neither added to nor withdrawn from the turbulent layer it quickly becomes uniform in moisture content throughout.

On the other hand, if water vapor is emitted from an evaporating surface it will be transported upward and scattered throughout the turbulent layer. Thus, as long as a stream of water vapor is flowing upward into the turbulent layer the moisture concentration will be highest at the base and will diminish upward, and a moisture gradient directed upwards will be established. Such a gradient could be maintained only as long as moisture continues to be added from below. When evaporation ceases the moisture will soon be distributed uniformly throughout the layer and the gradient will be destroyed. Similarly, if water vapor is abstracted from the base of the layer by condensation (dew or frost formation) the moisture concentration there will be reduced and as long as removal of moisture continues, a moisture gradient directed downwards will be maintained. The greater the intensity of turbulent mixing the greater will be the tendency toward the establishment of uniformity of moisture concentration, and the greater the evaporation or condensation required to maintain a constant gradient upward or downward. Similarly, the greater the moisture gradient which persists in an air column with a given rate of turbulent mixing, the greater will be the evaporation required to produce it.

From these facts it is evident that evaporation from any surface may be determined by taking into consideration the vertical distribution of moisture in the air and the intensity of turbulent mixing. The general form of an equation for evaporation based on these facts is $E=-A\,(dq/dh)$, in which A is the coefficient of turbulent mixing, or the Austausch coefficient of Willhelm Schmidt (24), and dq/dh is the rate of change of moisture concentration with respect to height above the evaporating surface. Observations required in order to measure evaporation are the moisture concentration at two levels within the turbulent layer, the heights of the two observations, so that moisture gradients may be obtained, and measurements of wind velocity at two or more levels to give the intensity of turbulent mixing. The moisture concentration in the air is measured as specific humidity. Within the height considered where air pressure is essentially constant the specific humidity is proportional to the vapor pressure.

Jeffreys (9) and Giblett (7) were among the earliest investigators who studied the problem of evaporation in terms of atmospheric turbulence. However, because of various nonrigorous assumptions regarding the nature of the Austausch coefficient, their results are limited and can be applied only to the evaporation from bodies of water.[1] Sutton (26), making use of Taylor's (32) researches, has extended Jeffrey's analysis by assuming that the Austausch coefficient varies with height. His theoretical work was found to be in very good agreement with experimental evaporation measurements for variously shaped areas. Schmidt (25) has made use of a formula devised by Ertel (6) for calculating the Austausch coefficient and claims to have measured the actual evaporation from a meadow.

During the last two decades great progress in the theoretical treatment of the mechanism of turbulent interchange has been made by various aerodynamicists, including Taylor (30, 31, 32, 33, 34), Prandtl (16, 17), von Kármán (10, 11, 12, 13), and others. In 1935 von Kármán (12) published an excellent summary of the problems associated with the various theories of turbulence. Rossby (21, 22) has made use of von Kármán's postulate of dynamic similarity and the concept of mixing length in his important researches on atmospheric turbulence. Sverdrup (27), working along lines explored by Rossby, has added much to our knowledge of the variation of the coefficient of eddy viscosity under changing conditions of thermal stability.

Although the theoretical treatment of problems of turbulence is still in the initial stage, sufficient has been accomplished to provide an understanding of the mechanism of evaporation and to permit the development of a formula by means of which evaporation from land and water surfaces alike may be determined.

A difficulty in the use of turbulent theory in the determination of evaporation is the fact that the laws of moisture transfer are different in the laminar and turbulent layers, being linear in the former and nonlinear in the latter. Leighly (14) avoided the turbulent layer entirely and confined his study to the laminar or boundary layer where the specific humidity gradient is linear and where the coefficient of diffusion can be used. Since the boundary layer is very thin if the air is in motion, Leighly's method would be useful only for determining evaporation from small areas (he thinks that the limit is a diameter not much greater than 4 feet). In fact, the making of moisture determinations at two levels in a layer as thin as the boundary layer would require a type of instrumentation not now available. With existing instruments it is quite impossible to recognize vapor pressure differences within a distance of a few millimeters. Thus, the use of Leighly's method must await the development of new instruments.

The problem of the difference in character of the moisture gradient and the process of moisture transfer in the boundary and turbulent layers confronted Sverdrup (28, 29) in his study of evaporation over the oceans. With the meager data at his disposal, consisting only of wind velocity and moisture concentration at one level in the turbulent layer, and the temperature and salinity of the ocean water, he was forced to consider the gradients in both the laminar and turbulent layers. Although this was accomplished with great ingenuity, the final computations can be considered only as rough indications of oceanic evaporation. Millar (15), in his study of evaporation from the Great Lakes, has approached the problem in much the same manner that Sverdrup did for the oceans, and his results are subject to the same limitations.

At this point it is possible to consider the physical limitations of the various empirical formulae based on Dalton's law, which have been presented in an earlier paragraph. These formulae are developed for determining evaporation from free water surfaces and make use of observations of the temperature of the water surface (from which the vapor pressure of the air in direct contact with the water is determined) and the vapor pressure and wind velocity at some level in the turbulent layer. Because of the previously mentioned difference in character of the moisture gradients and the processes of moisture transfer in the boundary and turbulent layers, it is impossible to derive simple empirical constants, to be used in connection with the difference between the vapor pressure of the water surface and the overlying air (e_w-e_d) and a wind factor, which will give more than a statistical approximation of the evaporation from free water surfaces. Using Sverdrup's method of integrating through the boundary layer, more satisfactory results, at least for large water bodies, could be expected. Under no circumstances could such observations be used for determining evaporation from land or transpiration from vegetation. Those formulae employing the so-called vapor pressure deficit (1), the difference between the saturation vapor pressure and the actual vapor pressure at some level in the air (E_d-e_d), are unrelated to the physical principles of evaporation, and cannot be expected to yield satisfactory results.

As an outgrowth of the researches on turbulence by von Kármán and Rossby and through discussion with them, a formula for determining evaporation from observations of moisture concentration and wind velocity in the turbulent layer has been devised and is here presented. The derivation of the formula follows directly from an expression for the Austausch coefficient obtained from the concepts of the mixing length and the shearing stress as developed by Prandtl and von Kármán. The derivation is straightforward and can readily be repeated by referring to the works of Rossby (21, 22) and Sverdrup (27). The formula itself is:

$$E=\frac{K_0^2\rho(q_1-q_2)u_2}{\log_e\frac{h_2}{h_1}\log_e\frac{h_2}{Z_0}}$$

in which K_0=von Kármán's coefficient.
ρ=density of the air.
q_1=moisture concentration at the lower level,
q_2=moisture concentration at the upper level,
u_2=wind velocity at the upper level,
h_2=height of the upper instruments,
h_1=height of the lower instruments,
and Z_0=roughness coefficient.

[1] A brief critical discussion of the studies of Jeffreys and Giblett may be found in Brunt (3), pp. 264-267.

The roughness coefficient is determined from observations of wind velocity at two levels by means of the following formula:

$$\log_e Z_0 = \frac{u_2 \log_e h_1 - u_1 \log_e h_2}{u_2 - u_1}.$$

Since the intensity of turbulent mixing is dependent on the wind velocity and the roughness coefficient and since the latter can be determined from wind velocities at two levels, it is possible to simplify the evaporation formula to the following:

$$E = \frac{K^2 \rho (q_1 - q_2)\ (u_2 - u_1)}{\left(\log_e \frac{h_2}{h_1}\right)^2}.$$

In the above formulae all values are in *CGS* units. The formula giving evaporation in inches per hour for an installation where the upper observations are taken 28.6 feet and the lower ones 2 feet above the ground is:

$$E = \frac{0.0274\ P(q_1 - q_2)\ (u_2 - u_1)}{T + 459.4}$$

where P is pressure in inches Hg

q_1 and q_2 are in grams per kilogram
u is wind velocity in miles per hour
and T is temperature in °F.

Expressed in terms of vapor pressure the formula is simplified further, and becomes

$$E = \frac{17.1(e_1 - e_2)\ (u_2 - u_1)}{T + 459.4}$$

in which e_1 and e_2 are the vapor pressures in inches of Hg at the lower and upper levels, respectively.

The formulae as presented are rigorously correct for an adiabatic atmosphere but in cases of thermal stability a correction must be applied for a precise evaluation of evaporation. It is now known that when the temperature and wind structure of the air attain certain critical values (**23**) the effect of turbulent mixing can be completely suppressed and the moisture transfer must then proceed by diffusion alone. Under conditions of light winds and temperature inversions, therefore, the values for evaporation or condensation, as the case may be, determined by the use of the above formulae, are too large. This introduces no serious error in computations of evaporation for periods of a day or longer as the amounts of moisture evaporated under conditions of stability are negligible compared with those amounts evaporated during adiabatic conditions. For the determination of the amount of dew or frost deposition the adiabatic formula becomes inadequate when atmospheric stability is such as to bring about a marked suppression of turbulence. A correction for the stability factor devised along the lines suggested by Rossby (**21, 22**) and Sverdrup (**27**) is being tested at the present time. However, since the amounts of condensation are quite small, again no serious error is involved in the consideration of moisture losses from watersheds.

Two experimental evaporation stations have been established; one at the Muskingum Climatic Research Center in Ohio and the other on Arlington Farm in Virginia. At the Arlington installation the instruments are located in a hay field on the relatively flat top of a gentle ridge. The hay had been cut shortly before the installation was made, and being composed of perennial grasses, continued to grow and remained more or less green throughout the winter. In each case a tower has been erected in such a manner that an instrument shelter large enough to house a hygrothermograph may be raised to a height of 28 feet and lowered at will (fig. 1). Another shelter accommodates a second hygrothermograph 2 feet from the ground. Records from these hygrothermographs, together with records from a barograph, are the only requirements for determining the specific humidity at the two levels. Recording anemometers at these levels supply the other information required in the evaporation formula (fig. 2). At the present time three hygrothermographs and four anemometers, mounted at different elevations on a tower, are being operated at Arlington to supply information for testing the validity of an expression derived to correct the adiabatic formula for cases of atmospheric stability.

Despite the fact that the hair hygrometer as an instrument for measuring relative humidity has many defects, the chief of which are the uncertainty of registration of very high and very low values, the hygrothermograph is found to be the most satisfactory existing instrument for our purpose.[2] In order to be certain of the results, six instruments have been used on each installation. All six instruments were first carefully calibrated in a moisture chamber where, by means of saturated solutions of various salts,[3] constant humidities could be maintained at various levels, and a separate calibration chart was prepared for each instrument. They were then grouped in pairs and were used in succession on the tower. Before two instruments were used they were given a background run side by side in a Weather Bureau shelter. After use they were given another background run and were again calibrated in the moisture chamber. Three datum pens were added to each instrument to permit correction for shrinking and stretching of the chart paper. Recently nonhygroscopic metal charts have been used in place of the moisture-sensitive paper charts and the index pens are no longer needed. Safe-guarded in this manner the results are felt to be reasonably reliable.

The first usable records of moisture concentration were obtained on October 15, 1938. Continuous daily observations on the moisture gradients have been made since the latter part of November. From these records it has been possible to get some indication of the diurnal changes in moisture concentration and gradient for certain air mass types and of the magnitude of the moisture gradients. Records of wind velocity at the two levels have been available only since November 23, 1938, and not until December 10, 1938, were actual determinations of evaporation begun.

Figure 3 shows the march of moisture concentration at the two levels for two days in early autumn during which time a modified Polar Continental air mass remained over the area. The sky was clear and moderate temperatures prevailed. The air mass was relatively stagnant with light and variable winds. Significant radiational cooling occurred throughout the night and a moderate ground fog condition limiting visibilities to 1 to 2 miles was observed at the site of the experimental station.

During the first night the moisture concentration of the air dropped to a minimum of 5.4 and 5.8 grams in the lower and upper levels due to abstraction of moisture by condensation at the ground. As soon as the ground began to

[2] An automatic dewpoint recorder has been devised by the authors and a laboratory model has been built by Dr. L. R. Hafstad of the Carnegie Institution of Washington and J. C. Owen of our staff. If satisfactory field instruments can be made they should be more accurate than any type of instrument now available.

[3] The salts used and the relative humidities which they maintain at room temperatures are as follows: KNO_3, 95 percent; $NaCl$, 75 percent; $Mg(NO_3)_2.6H_2O$, 52 percent; $MgCl_2.6H_2O$, 32 percent; $LiCl$, 16 percent.

FIGURE 1.—Evaporation instrumental installation at Arlington Farm, Va.

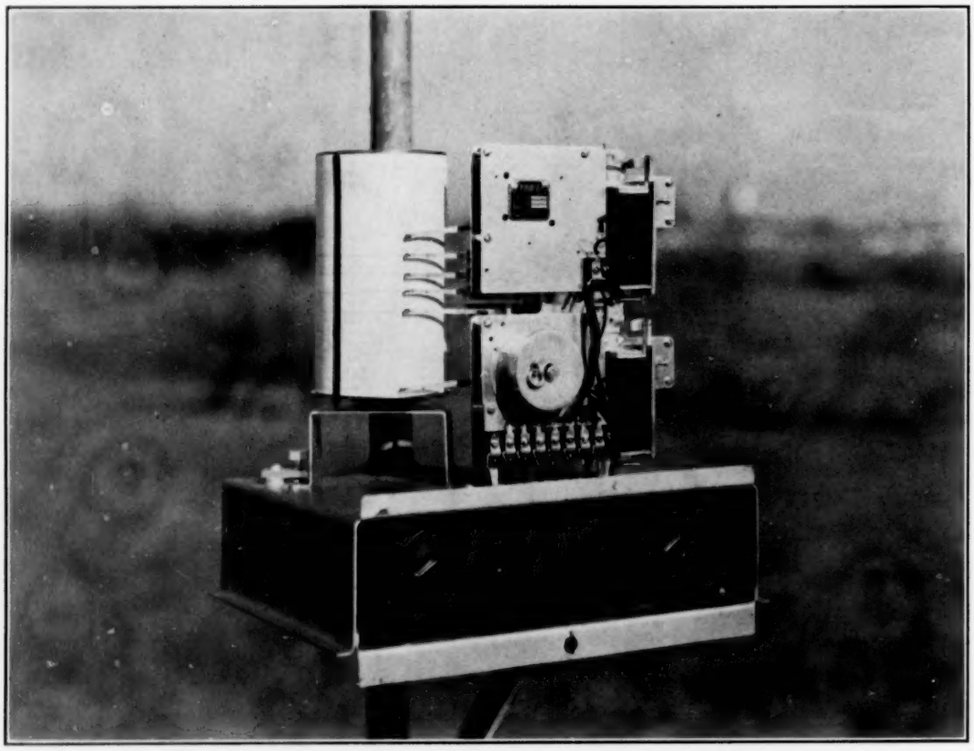

FIGURE 2.—Recorder for wind velocity at two levels and wind direction at one level, designed especially for evaporation studies. A similar instrument giving a synchronized record of wind velocity at four levels and wind direction at one level has recently been installed.

TABLE 1.—*Data for the computation of evaporation at Arlington Farm, Va., for the 24-hour period Jan. 27, 1939*

	Hour ending—A. m.											
	1	2	3	4	5	6	7	8	9	10	11	Noon
Upper observations:												
Relative humidity	66.2	70.8	75.2	80.1	81.5	75.1	52.0	45.4	43.5	45.2	41.0	39.4
Temperature	20.8	20.3	20.1	18.9	18.7	19.3	22.8	23.3	24.0	25.1	26.5	28.5
Vapor pressure	.071	.074	.078	.079	.079	.075	.061	.055	.054	.059	.057	.061
Wind	5.0	3.8	4.0	1.8	1.5	3.5	9.0	5.8	13.5	12.8	19.2	12.5
Lower observations:												
Relative humidity	74.6	76.7	80.9	84.9	87.9	84.2	58.8	52.5	51.4	50.0	45.5	42.0
Temperature	19.4	18.5	17.5	16.5	16.0	16.5	20.5	21.0	22.4	24.9	26.9	29.4
Vapor pressure	.075	.074	.074	.074	.075	.073	.062	.057	.060	.065	.065	.067
Wind	3.2	2.0	1.8	1.0	.2	1.5	5.8	3.5	7.5	8.2	12.8	8.5
Difference:												
Vapor pressure	.004	.000	−.004	−.005	−.004	−.002	.001	.002	.006	.006	.008	.006
Wind	1.8	1.8	2.2	.8	1.3	2.0	3.2	2.3	6.0	4.6	6.4	4.0
Evaporation [1]	.0003	.0000	−.0003	−.0001	−.0002	−.0001	.0001	.0002	.0013	.0010	.0018	.0008

	Hour ending—P. m.											
	1	2	3	4	5	6	7	8	9	10	11	Midnight
Upper observations:												
Relative humidity	36.5	34.2	31.0	32.0	34.1	35.3	35.5	35.5	37.6	41.0	43.0	47.5
Temperature	30.5	32.5	34.0	34.0	34.0	33.0	32.3	31.7	31.0	30.0	28.3	26.5
Vapor pressure	.061	.063	.061	.062	.067	.066	.065	.063	.065	.068	.065	.067
Wind	13.5	15.2	14.8	12.2	14.5	11.2	8.0	7.2	5.0	3.5	2.8	4.2
Lower observations:												
Relative humidity	38.0	34.2	32.0	34.5	36.9	39.3	41.5	41.1	43.1	50.0	64.0	71.4
Temperature	31.9	33.9	34.9	33.6	32.9	31.4	30.4	29.4	29.4	26.9	22.9	21.4
Vapor pressure	.068	.067	.065	.066	.069	.069	.070	.066	.069	.071	.076	.079
Wind	9.2	10.5	9.8	9.8	9.0	8.0	5.0	4.2	2.8	1.8	.2	1.2
Difference:												
Vapor pressure	.007	.004	.004	.004	.002	.003	.005	.003	.004	.003	.011	.012
Wind	4.3	4.7	5.0	2.2	5.5	3.2	3.0	3.0	2.2	1.7	2.6	3.0
Evaporation [1]	.0011	.0007	.0007	.0003	.0004	.0003	.0005	.0003	.0003	.0002	.0010	.0013

[1] Negative evaporation is condensation. Totals for the period. Evaporation 0.0126 inches, Condensation 0.0007 inches.

warm up after sunrise and evaporation commenced, moisture concentration rose rapidly, beginning at the lower level and producing a reversal in the gradient. Shortly before noon thermal convection had developed to a point where the moisture was carried to the upper air faster than it was received from the ground and the concentration at both levels diminished about 0.8 grams. In late afternoon, with a diminution of convection, the evaporation again exceeded the rate of transport aloft and the moisture concentration rose to the high point of the day. Between 6 and 7 p. m. the cooling of the ground surface began, and soon the concentration at both levels was the same. With continued cooling condensation was initiated, and as moisture was abstracted from the lower level the gradient was reversed, and the concentration at both levels diminished throughout the night. In the morning there was a heavy dew deposit.

The same sequence of conditions was repeated the next day; first an upward shift of gradient followed by a rapid increase of moisture concentration as evaporation proceeded; then a diminution of concentration with a continued upward-directed gradient as thermal convection carried the moisture to the drier levels aloft; then as convection subsided a rapid increase in concentration; and finally, with the onset of ground radiation at the end of the day, condensation, a gradient directed downward, and a rapid diminution of moisture.

A few days later, with the passage of a well-marked front the transitional Polar Continental air mass was displaced by a fresh polar air mass. The moisture concentration dropped within the course of a few hours from about 10.5 to 4.0 grams. The moisture gradient pattern for the 2 days following is shown in figure 4. Except for scattered cirrus and a few scattered cumulus clouds during the afternoon the sky was clear throughout the 2-day period. For nearly the entire first day the wind direction was predominantly from the west and west-northwest with velocities ranging from 5 to 15 miles per hour. The moisture gradient, although small, was directed upward for approximately 28 hours after the invasion of the polar air mass. The moisture concentration remained almost stationary at about 4 grams until approximately 3 p. m., when a moderate amount of convection forced a small decline. It is of interest to note that scattered cumulus clouds were observed between 3 and 5 p. m., which coincided with the observed decline in moisture concentration. During the evening evaporation continued and the concentration rose more than a gram. Not until after 10 p. m. did the gradient turn downward and condensation commence.

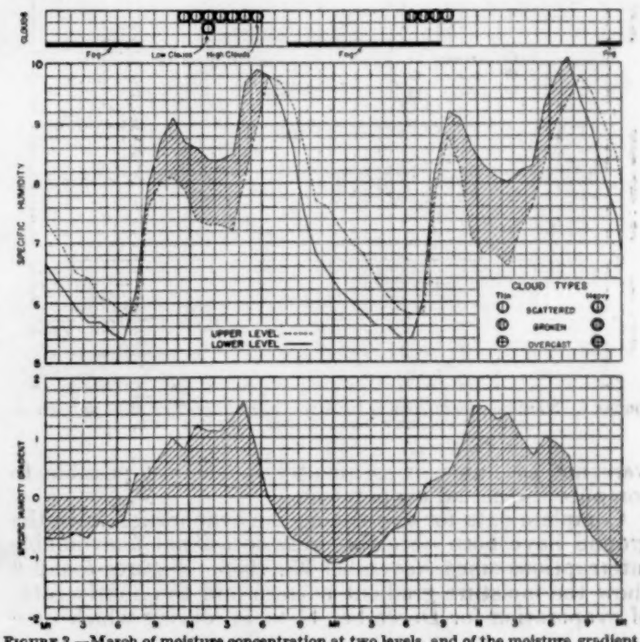

FIGURE 3.—March of moisture concentration at two levels, and of the moisture gradient, for October 15 and 16, 1938. Arlington Farm.

At this time the wind had subsided, becoming variable with velocities generally less than 2 to 3 miles per hour. Thereafter during the night, with moisture abstraction going on at the ground, the moisture concentration slowly declined. The gradient pattern of the second day resembled those of the 2 earlier days shown in figure 3,

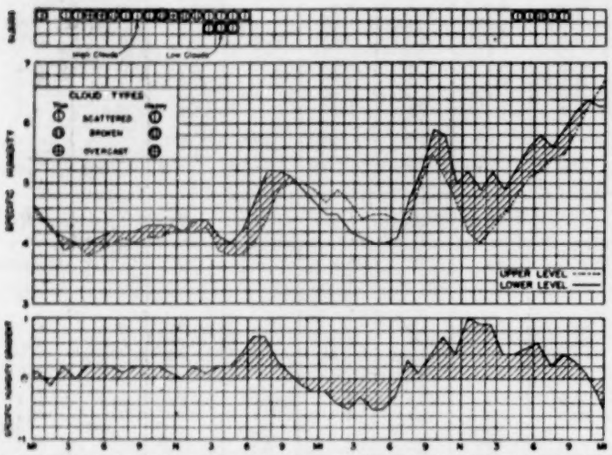

FIGURE 4.—March of moisture concentration at two levels, and of the moisture gradient, for October 21 and 22, 1938. Arlington Farm.

although the rate of evaporation was considerably reduced. The important difference in pattern is that the moisture gradient was directed upward until 11 p. m., with the moisture concentration continuing to rise until that time.

For the cases already discussed, wind velocity gradients

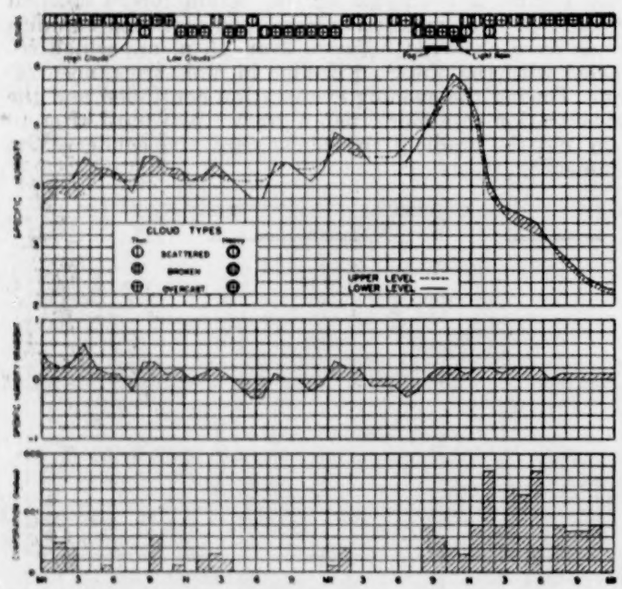

FIGURE 5.—Moisture concentration at two levels, moisture gradient and hourly evaporation for December 11 and 12, 1938. Arlington Farm.

were not available, consequently it was not possible to compute the actual evaporation.

Complete data for calculating the evaporation from the ground have been obtained with occasional unavoidable interruptions since November 23, 1938. Figures 5 and 6 show the moisture gradient pattern and the hourly rates of evaporation for December 11 to 14, during which time a Polar Continental air mass displaced a southerly current of well-modified polar air. On December 11, the synoptic weather chart indicated the presence of a well-modified returning flow of polar air over the eastern United States. The sky conditions as observed at the Washington airport adjoining the Arlington Farm, were quite variable from hour to hour. The thin, broken to overcast, altostratus clouds which predominated during the early morning and forenoon thickened to a nearly continuous overcast with a base at 6,000 to 7,000 feet during the afternoon and evening. During this time the specific humidity gradient was directed upward. Between 5 and 7 p. m. the clouds became scattered and broken and radiational cooling of the ground hastened the usual reversal of the specific humidity gradient. As the overcast thickened again, the gradient shifted upwards temporarily for an hour. Thereafter the gradient was directed downward except for a period between midnight and 3 a. m. of December 12. The upward gradient at this time was probably due to a

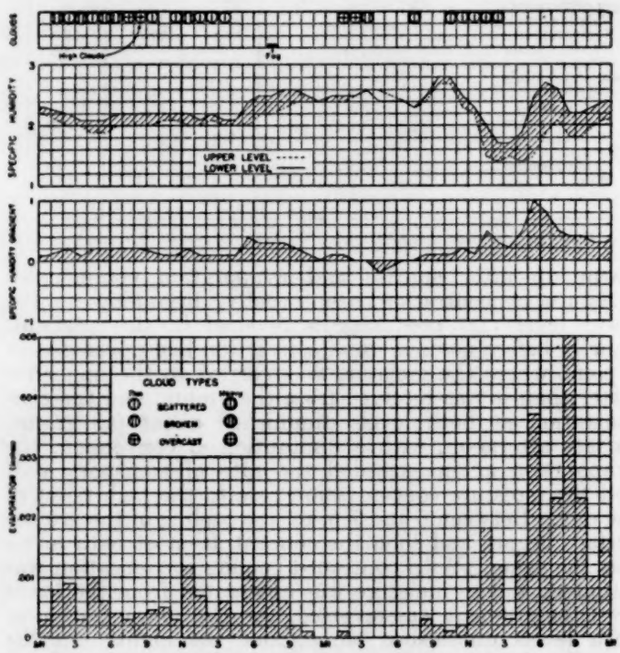

FIGURE 6.—Moisture concentration at two levels, moisture gradient and hourly evaporation for December 13 and 14, 1938. Arlington Farm.

slight increase in surface temperature caused by the downward transport of heat by turbulence induced by the increased wind velocities which prevailed during this period.

During the early morning of December 12, the clouds were, in general, high and scattered and calm or extremely light winds prevailed. The moisture gradient continued downward and a light dew formation resulted. At 9 a. m. the sky became overcast with upper altostratus and lower strato-cumulus decks heralding the approach of a cold front. Occasional sprinkles were noted during the hour ending at 9 a. m., and light rain was observed between 10:10 and 11:25 a. m. The amount of rainfall, however, was less than 0.01 inch. The front, which marked the boundary of Polar Continental air, passed the station at approximately 11 a. m. and was associated with a wind shift to the northwest and a dissipation of the strato-cumulus deck. During the ensuing 30 hours the wind remained in the northwest with veloci-

ties generally between 8 and 15 miles per hour. The specific humidity gradient was directed upward for 2 hours prior to the frontal passage and continued to be directed upward until the morning of the 14th. The gradient shifted downward at this time and a heavy frost ensued.

It is to be noted that on the 13th there was no drop in specific humidity resulting from large scale thermal or convective turbulence such as was illustrated in figure 3. This is explained by the fact that convective turbulence was limited to the thick layer of polar air, within which mixing by mechanical turbulence had already established complete uniformity of moisture concentration, thus precluding the possibility of replacement of the air at the level of the observations by drier air from aloft.

On December 14, however, the wind velocities in the polar air were light and variable and the thickness of the mechanically turbulent layer was much less than that on the 13th. From 11 a. m. to 3 p. m. the characteristic convective turbulence was manifested by a steady drop in the specific humidities in spite of the fact that evaporation was continuously adding moisture to the atmosphere. A secondary decrease in the specific humidities beginning at 8 p. m. is also due to mixing with drier air aloft. The wind velocities increased at this time, shifting from south at 3 miles per hour to west-northwest at 15 miles per hour, causing an increase in surface temperature from 38° to 42°.

The water loss from the land surface at Arlington Farm, combining evaporation from the soil, evaporation of dew and frost, and transpiration, for the 4 days from December 11 to December 14 was 0.0026 inches, 0.0137 inches, 0.0132 inches and 0.0239 inches respectively.

The station was operated without interruption from November 23, 1938 until February 7, 1939 and hourly evaporation has been determined for this entire period. Figure 7 shows the daily evaporation and condensation for the month of January. In table 1 the type of information obtained and hourly evaporation values for January 27, 1939 are presented merely for illustrative purposes.

During the first 4 days in January the ground surface was dry and the moisture was apparently removed chiefly by transpiration (37). Variable high scattered clouds and light variable winds prevailed during this period and appreciable amounts of dew condensed during the early morning hours. On January 5 a low stratus overcast prevailed throughout the greater portion of the day. Intermittent sprinkles and occasional light rain totaling 0.07 inches occurred during the 24-hour period. In spite of the cloudy conditions and the precipitation a measurable moisture gradient directed upward was detected and 0.0103 inches of evaporation occurred. The following day, January 6, the skies were relatively clear, moderate wind velocities were observed, and the evaporation was greatly increased, amounting to 0.0544 inches. On the 7th, 8th, and 9th variable high clouds to clear skies prevailed but the daily evaporation totals were, as was to be expected, less than that of the 6th when the ground surface was moistened by the previous day's rainfall. On the 8th the evaporation was slightly greater than on the 7th or 9th and may be explained by the moderate wind velocities, occasionally reaching 22 miles per hour. Light rain amounting to 0.07 inches fell between 7 a. m. and 9:30 a. m. on January 10. In spite of the moisture on the ground and a moderate south-southwest wind that varied between 8 and 12 miles per hour, the evaporation amounted to only 0.0276 inches. The suppression of evaporation on this day may be explained by the diminution of the moisture gradient due to the invasion of more moist air from the south, causing an increase in specific humidity from 3.5 grams to approximately 7 grams. On the following day, there was only slightly more evaporation. However, by the morning of the 12th fresh polar air had invaded the area and the specific humidity dropped to 2.2 grams. The wind blew prevailingly from the northwest with a velocity ranging between 5 and 15 miles per hour, and in spite of a high overcast the evaporation attained a value of 0.0535 inches. The increased evaporation into polar air masses, which has been found consistently in our observations, was anticipated on the basis of the cycle of air masses (8, 35).

The high alto-stratus overcast that was present throughout the 12th steadily lowered and thickened, heralding the approach of a warm front storm. On the 13th a mixed precipitation of freezing rain, sleet and snow fell throughout the greater part of the day. On the 16th a light snow fell between 6 a. m. and 11 a. m. On the 18th snow began falling shortly after midnight and continued throughout the day until 10 p. m. A light snow, associated with an upper cold front, occurred on the 20th between

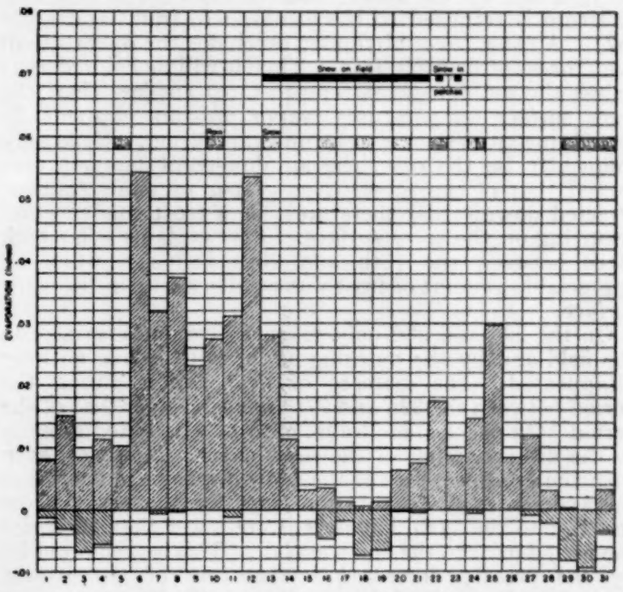

FIGURE 7.—Daily totals of evaporation and condensation for the month of January, 1939. Arlington Farm.

5 p. m. and 9 p. m. Thus from the 13th through the 20th the site of the evaporation station was covered with snow ranging in thickness from 1 to 6 inches.

During this period the blanket of snow was fundamentally responsible for the suppression of evaporation. A snow cover may suppress evaporation in a number of different ways, although it is by no means intended to imply that the moisture losses by evaporation from a snow field may not be large when suitable atmospheric conditions prevail. Because of the difference in the physical characteristics of a snow cover and a grass cover there must obviously be a difference in the roughness factor characterizing the type of surface and a consequent difference in the intensity of turbulent mixing.

Rossby and Montgomery (22, p. 10) using observations published by Shaw have determined the roughness factor for an open grassland. Sverdrup (27, p. 44) has made a similar determination for a snow field from observations taken in West Spitzbergen. Using these determinations of roughness it is found that under otherwise similar conditions the evaporation from the meadow would exceed by approximately 50 percent that from the snow field.

Similar calculations for Arlington Farm showed a reduction of the roughness factor during the period when the ground was snow covered that was in excellent agreement with this figure.

An important factor governing the rate of evaporation from the snow is the temperature of the snow surface. It is well known that a snow surface radiates energy as a black body (38) and on a clear calm night, excessive inversions of temperature may be established in the air next to the snow. During the daylight hours much of the incident radiation is reflected and the snow surface temperatures may remain well below the dewpoint temperatures of the air. In any event the temperature of the snow surface must remain at the freezing temperature until all of the snow is melted. Comparing a grass-covered field with a snow field, the former will also radiate energy like a black-body but during the daylight hours most of the incident energy will be absorbed and the surface temperatures may be greatly increased, resulting in increased transpiration of the plants. Transpiration may be regarded as the most effective mechanism whereby moisture is returned to the atmosphere from land areas (37). A snow cover obviously precludes the operation of the process of transpiration. Thus it will be evident that unless the air dew-point temperatures are less than the snow surface temperatures (vapor pressure gradient directed upwards) there can be no evaporation. If, as may frequently be the case, the air dew-point temperatures exceed that of the snow cover (vapor pressure gradient directed downwards) there must be a frost condensation occurring on the snow surface. This explains what took place between the 16th and 20th inclusive when an appreciable amount of frost was condensed upon the snow surface.

On the 22d and 23d only patches of snow remained on the field and by the morning of the 24th it had entirely disappeared. The increase of evaporation during the period between the 22d and 27th inclusive over that of the period 14th to 21st, inclusive, is to be attributed directly to the disappearance of the snow cover. However, even with the disappearance of the snow it is to be noticed that the average daily evaporation rates for the period from the 21st to the 27th, inclusive, were lower than those for the period prior to the first snowfall. This is accounted for by the greatly decreased temperature of the ground during the last half of the month.

Cold and dry Polar Continental air occupied the area on the 27th but was displaced by a southwesterly current of transitional tropical air on the 28th. The dew-point temperatures of the polar air averaged approximately 12° but increased to about 20° in the modified air. The ground temperatures were still quite low and with the invasion of the modified air with increased specific humidities, the moisture gradient was directed downward for a good portion of the day and appreciable condensation of frost occurred. The 29th was overcast and light rain began at 11 a. m. and continued through midnight. The cloud base which remained below 1,000 feet lowered to the ground in the evening, resulting in foggy conditions. On the 30th a low stratus overcast with ceilings varying between 200 and 600 feet and light rain or mist and fog persisted during the entire day. The rain ceased in the early morning of the 31st when a polar air mass again invaded eastern United States. Practically no evaporation occurred on the 29th or the 30th. On both of these days, however, significant amounts of condensation occurred. The small evaporation of the 31st was associated with the invasion of the polar air mass. The total amount of evaporation at the Arlington Farm for the month of January 1939 amounted to 0.4747 inches. The total amount of condensation as computed was 0.0632 inches. It is recognized that this latter figure may be somewhat exaggerated.

In general, most researches on the problem of evaporation have been directed toward the determination of moisture losses from bodies of water. This has led to a deficiency in basic and quantitative information regarding actual moisture losses from watersheds or land surfaces. Studies of the evaporation from free water surfaces alone have proved wholly inadequate from the standpoint of soil conservation. What is required is the actual moisture losses from all types of geographic surfaces, or in other words, a quantitative estimate of the evaporative phase of the hydrologic cycle. With this information the soil conservationist will then be able to interpret the interrelations between climatic forces and land utilization (**36**).

In an effort to supply this much-needed information a method for determinining the evaporation from either land or water areas has been presented in this preliminary report. The practicability of the technique has been completely demonstrated. It is hoped that with proper instrumental installation it will be possible to determine transpiration rates and moisture requirements of various field crops and forest trees, the effectiveness of various moisture conserving practices, and the relative importance of evaporation and transpiration in the hydrologic cycle. However, the question of satisfactory instrumentation has not been entirely solved and the validity of various theoretical assumptions has yet to be tested. These questions are expected to be discussed further in a detailed report on the problem of evaporation to be published in the near future.

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VALLEY-HEAD CLOUD WINDOWS

By RONALD L. IVES
[Boulder, Colo., September 1938]

"Windows," which hold their positions, regardless of cloud motion, have been observed in the cloud strata over the heads of many glaciated valleys in the Colorado Front Range area.

Observations during the summer of 1938, when abnormal wetness in the foothills and on the adjacent plains increased the cloudiness on the east flank of the Front Range and broke up the normally present "convection sheets" into valley winds, indicate that the cloud windows are caused by these valley winds.

Following the courses of the valleys upward from the plains, the winds have a temperature at 12,000 feet of about 75°. Mountain air, at the same time and elevation, has a temperature of about 50°, and has a greater humidity than the valley air.

Cloud strata are at 12,500 to 13,000 feet and 14,000 to 16,000 feet: The lower stratum being confined closely to the range; the upper stratum covering the parks between the ranges, and sometimes extending several miles over the plains.

Valley winds, on reaching the cirques at the valley heads, are diverted sharply upward, and the clouds are evaporated as the winds rise through them. Clouds that drift into these updrafts are immediately dissipated. No cloud

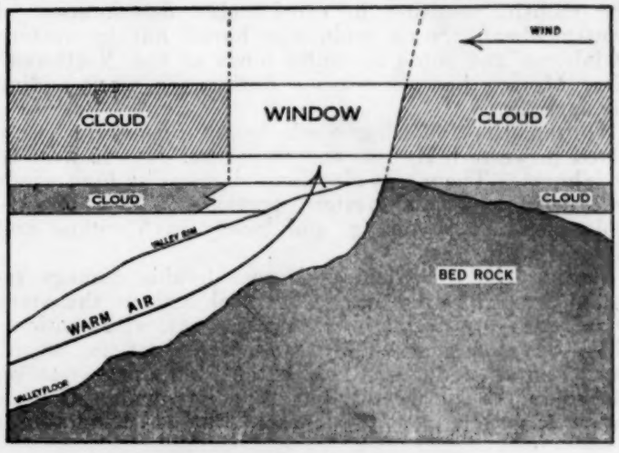


FIGURE 1.—Typical valley-head cloud window.

wisps are formed over the cloud windows, even in the cold stratum above 16,000 feet, indicating that the humidity of the uprising valley air is low, even after it has absorbed the moisture contained in many cubic feet of cloud.

The occurrence of nonmoving windows in the cloud strata of a mountain region should, therefore, immediately suggest the presence of warm, upward-diverted valley winds.

The type location for these cloud windows is the head of Fourth of July Gulch, Boulder County, Colo.; lat. 40°01′ N., long. 105°41′ W.; shown on the U. S. G. S. Rocky Mountain National Park quadrangle. These observations were made during the progress of research assisted by the Penrose Fund of the American Philosophical Society. The writer is indebted to Bruce R. Snow, of the University of Colorado, for check observations.

DUSTSTORMS OF 1938 IN THE UNITED STATES

By ROBT. J. MARTIN

[Weather Bureau, Washington, February 1939]

The duststorms of the year just ended were far less extensive and noteworthy than in several preceding years,[1] but there were some sections of the country, particularly in the Dust Bowl itself and locally to northward, where occasional storms were as severe as any reported during recent years. The most severe storms generally came early in the year, particularly during the winter and early spring months when winter wheat was most susceptible to damage from drifting soil. Reports were all too frequent of tender growth being cut and eroded away by flying grains of sand or of young growth being buried.

While there were a few reports of dust being observed in central and eastern sections of the country, especially during March and May, and locally in several other months, duststorms were not nearly so widespread as in 1934, 1935, and 1936.

January.—Precipitation during January was subnormal in more than half the country with the greatest deficiencies noted in portions of the Plains States, the upper Mississippi Valley, the Southwest, the northern Rocky Mountain region, and the Pacific States. Portions of Kansas and Nebraska had only 3 to 25 percent of the normal January fall. Precipitation was normal or decidedly above in a wide belt reaching from the Rio Grande Valley in Texas eastward and northeastward and several stations in southwestern Texas, southeastern New Mexico, Arkansas, Iowa, and Wisconsin had more than 200 percent of normal precipitation.

Because of dry subsoil and greatly subnormal rain and snow, duststorms were rather numerous and severe during January in portions of the Dust Bowl. Some damage was done by shifting soil in Nebraska and duststorms were especially severe in Kansas on the 13th of the month, resulting in considerable deterioration of winter wheat. Some grain was blown out in western Oklahoma and some in sandy lands of the Northwest. New Mexico had duststorms during the week ending January 18.

During the following week heavy duststorms were noted in western Kansas and on several days in western Oklahoma. There was also some damage by high winds and drifting soil in western portions of New Mexico, Colorado, and Wyoming, and locally in Montana and Nebraska.

During the following week considerable damage resulted from blowing in west-central and northwestern Oklahoma; duststorms in western Kansas, with considerable soil movement, injured winter wheat in several southwestern counties. Less extensive damage was reported in the Northwest, but Wyoming indicated some injury to grains from this cause. Rather severe storms were experienced in eastern New Mexico. Over the northern Great Plains light dust was reported as far north as Montana and in extreme western Minnesota on the 24th. Light dust was noted as far east as Tennessee on the 12th and 18th and was also reported during the latter part of the month in portions of Illinois and Mississippi.

In southern sections of the Great Plains light dust was reported on as many as 9 days, nearly all during the latter half of the month. Brownsville, Tex., had light dust on 3 days. The storms were most severe in the Dust Bowl, that is, portions of western and southwestern Kansas, western Oklahoma, northwestern Texas, northeastern New Mexico, and southeastern Colorado. In western Kansas, particularly in the areas around Sublette, the dust movement was sufficient to cause marked delay in transportation schedules. A train of the Dodge City and Cimarron Valley branch of the Santa Fe was delayed 18 hours by impassable drifts of dust. A combination snow and dust plow was required to clear a pile of dust 3 to 6 feet deep and 1,400 feet long from the tracks. At times during these storms, not only in Kansas, but in other portions of the Dust Bowl, and locally as far north as Wyoming, visibility was reduced to zero, flying schedules were canceled, street lights were necessary and a marked increase in respiratory troubles was reported. Several deaths occurred from automobile accidents during the times of least visibility.

In Colorado a heavy "duster" on the 16th covered practically all southeastern counties and on the 23rd swirling clouds of dust continued for 60 consecutive hours, reducing visibility to zero or one city block throughout Baca and eastern Prowers Counties. The damage with respect to soil erosion was noteworthy during this storm.

The observer at Goodwell, Okla., reported 7 days with heavy dust and several days on which visibility was 75 feet or less. The storms of the 24-25th were the most severe in northwestern Oklahoma and, according to competent authority, were the worst ever experienced in that section.

February.—February brought good rains or snows to most of the Plains States, particularly Texas, Oklahoma, Kansas, and portions of the Dakotas and Nebraska. Much of the precipitation was in the form of snow which aided materially in reducing the number of duststorms. Because of insufficient precipitation in portions of Colorado dust blowing caused considerable damage to wheat in Las Animas County and a large acreage in the western part of the State was abandoned. Generally, the rains of the month were not sufficient to restore deficient subsoil moisture, however, and there was no permanent let up in soil blowing.

The presence of dust in the upper atmosphere was shown by highly colored sunrises and sunsets as far east as Reading, Pa. At Marquette and Sault Ste. Marie, Mich., dust

[1] For accounts of previous duststorms, see the following REVIEWS: 1934, January and May; 1935, February to May, inclusive; 1936, March, May, and December; 1937, April.

mixed with snow fell on the 13th. At Sault Ste. Marie the amount of dust was estimated to exceed 5 tons per square mile.

In New Mexico duststorms were fairly general in Union, Quay, Curry, Harding, Roosevelt, and Lee Counties on the 2d; visibility during the day averaged about ¼ mile. There was considerable wind movement over the northeastern counties of the State during the last 2 weeks of February but very little dust blowing because of the general precipitation in that area near the close of the month. Dense duststorms occurred in Kansas on the 1st and 8th and light storms on several other days during the first half of the month. Light local soil blowing was reported in Nebraska, South Dakota, and Colorado early in February. The storms of the 5th, 7th, and 12th were most severe and widespread in Colorado with durations of 6 to 8 hours and minimum visibilities ranging from zero to 100 yards; at Pueblo the dust cloud was a mile high. Precipitation began over the eastern plains of Colorado on the 15th and dust subsided for the remainder of the month; during the first 15 days dust had followed any wind velocity exceeding 15 miles per hour. As far north as Montana, severe dust blowing was reported, in areas not locally snow-covered, in portions of Cascade, Fergus, and Gallatin Counties.

The observer at Dodge City, Kans., reported that the snow and rain the last of February went down into the soil not more than 5 inches and usually less than that. He also stated that this precipitation did not terminate the dust threat in southwestern Kansas and that indications were for much dust unless heavy rains came very soon.

March.—March brought above-normal precipitation to much of the central and southern Great Plains area and to portions of eastern New Mexico, but a large portion of central New Mexico, the Dakotas, Nebraska, Wyoming, and part of southeastern Montana had subnormal falls. Duststorms were more extensive than in any other month of 1938 and were reported generally from the Rocky Mountain States eastward to the Ohio Valley and Tennessee, and from Texas and Mississippi northward to the Canadian border. At some stations in more eastern sections the presence of dust in the upper atmosphere was shown only by colored sunsets or sunrises and by muddy rains and snows, but in portions of Kentucky and Tennessee, and locally in Wisconsin, Illinois, and Mississippi, the dust was thick enough materially to limit visibility.

In southern Plains sections the frequency was rather evenly distributed throughout the month, although there was a general tendency for the more severe storms to group near the close. Farther north storms were most general and severe during the latter half of March with some reports of grain blown out near the close as far north as Minnesota. At Pueblo, Colo., the storm of the 24th made highway travel extremely dangerous; flying schedules were canceled and business houses and homes were quickly "filled" with fine red silt. In Colorado, although precipitation was generally above normal for March, hardly a day passed without some dust being raised, substantiating the fact that at times heavy dust began blowing from fields within an hour or two following rainfall of half an inch or more. The worst part of the blowing season in Colorado, normally from February 15 to March 31, was marked by some rather severe storms, although the precipitation, especially snow, did well in checking the destructive and irritable storms during that period; a moderate duststorm of 7 hours' duration prevailed in southern Baca County on the 3d. On the 4th visibility was reduced to from ½ mile to 200 feet in portions of both Baca and Prowers Counties for several hours. On the 14th a storm lasted about 10 hours in Baca and 3 hours in eastern Prowers County, visibility ranging from 50 feet to zero at times; other storms were reported on the 2d, 21st, 24th, 26th, and 29th.

In Kansas light dust was reported in Dodge City on 13 days, thick dust on 9 days, and dense dust with visibility of less than ¼ mile on the 2d, 3d, and 14th. A letter from the official in charge at Dodge City, dated April 5, 1938, calls attention to the fact that the day after an inch of rain had fallen on the 27th–28th, dust was observed in all sections of the State. He also added that it was necessary for the Santa Fe Railroad to plow the dust from the track about twice a week between Dodge City and Boise City, Okla.; the dust piled on the track ranged in depth from 6 inches to 5 feet. It was also stated that 12 hours after a rainfall of 0.75 inch, the dust was so dense that visibility was less than ½ mile.

In New Mexico storms were most prevalent on the 3d, 12th, 14th, 16th–17th, 21st–22d, 25th–26th, and 30th. The storm of the 25th–26th spread over the entire State and was accompanied at times by visibilities of less than ¼ mile and wind velocities of 30 to 40 miles an hour. The storm of the 30th was most severe; it began about 10 a. m. in the northeast and under the influence of winds of 30 to 50 miles per hour and the dry effect of the previous duststorms, especially those of 25th–26th, caused blowing sand over the eastern and southern portions of the State; it ended early on the morning of the 31st.

The adverse effect of the duststorms of the month was shown in occasional reports of damage to winter wheat in portions of the Oklahoma Panhandle, southwestern Kansas, parts of New Mexico, and some States to northward, including North Dakota, Minnesota, and Washington.

April.—The Plains States from western Kansas northward through South Dakota, and portions of North Dakota had above-normal precipitation during April; heavy falls were also reported in eastern Colorado and most of Wyoming, but half of Kansas, nearly all of Oklahoma, much of Texas, and practically all of Montana had decidedly subnormal rain.

Because of previously dry subsoil and insufficient surface-soil moisture, duststorms were again widespread and were reported from Texas northward to the Canadian border and from New Mexico and Montana eastward to Illinois. Nearly all of the most severe storms in southern sections occurred before the 15th; extreme southwestern Kansas had severe storms on several days early in the month but only light or thick dust was reported from this State during the latter half. In Arkansas and Illinois dust was most noticeable after the 15th while in portions of Nebraska, the Dakotas, Minnesota, Iowa, and New Mexico the storms were distributed rather uniformly.

Some damage to winter wheat was reported in southwestern Texas the first week of April, in New Mexico during the week ending the 12th, locally in Montana during the first week, and in portions of the southern Great Plains and southern Rocky Mountain region near the close. In Colorado "Black Blizzards" again "squelched" southeastern counties; in points of severity and destructiveness they were unequalled. Even though precipitation had been generally sufficient for growing crops during February and March, wind-whipped dust cut plants into shreds or completely covered them, thus preventing vegetation from gaining a foothold. In extreme eastern counties south of the 89th parallel, duststorms continued with greater severity than in previous months and were much more frequent. Fields were badly blown and dunes as much as 5 feet high resulted from the dust and sand in southern Lincoln County. Windshields on automobiles

were pitted by the flying sand. After the 7th, duststorms, locally of considerable severity, occurred every day, except on the 17th, 20th, and 21st, and reduced visibility daily to a few hundred feet and frequently to zero. Even rains of an inch or more failed to bring surcease for more than 6 hours and lister furrows were completely leveled after a few days of blowing.

May.—May brought above-normal precipitation to all the Plains States, except Texas and New Mexico; in Kansas the monthly total was more than twice the normal and valuable excesses were also recorded in Nebraska, Montana, Colorado, and Oklahoma; in New Mexico precipitation for the month was 55 percent of normal, in Texas 86 percent. During the week ending May 17 there was unusual wind movement in portions of the Great Plains area and duststorms occurred in southwestern Kansas, western Oklahoma, and central and western North Dakota.

Despite the heavy, beneficial rains, dusty conditions were more prevalent east of the Mississippi than for several months past; dust was noted as far east as South Carolina on several dates and from the 15th to the 18th dusty conditions were reported from the eastern Gulf States northward to the Lake Region; a minimum visibility of 100 feet occurred in portions of Indiana on the 16th. In nearly all instances, however, these storms were light in character to eastward of the Mississippi, but in western areas, particularly throughout the Great Plains, they were occasionally Statewide and were rather frequent. The most extensive storms generally occurred during the first half or near the middle of the month in Iowa, Minnesota, and the Dakotas, while in Montana the most severe storms occurred in extreme northeastern counties on the 13th. The storms in western North Dakota on the 1st, 13th, and 15th were the worst ever observed in that area. Further south the number of dense storms was less; visibilities in New Mexico were seldom less than ½ mile and in northwestern Texas dense dust occurred on only 3 days.

Low seasonal wind velocities in conjunction with above-normal precipitation for the third consecutive month practically ended destructive duststorms, at least temporarily, in Colorado. Even in southeastern counties vegetation gained a foothold and this further lessened the probability of dust erosion. Excessively strong winds on the 1st, however, raised dust throughout the eastern portion of the State and caused heavy erosion in southeastern counties where the storm continued throughout the 2d–3d. A destructive storm occurred in Baca County on the afternoon of the 13th and another continued throughout the 17th. Other light storms occurred in southeastern counties on the 14th, 15th, 16th, 18th, 25th, 27th, and 28th, but most of these were local in origin and where precipitation was more or less deficient.

At Dodge City, Kans., light dust occurred on May 1, 2, 3, 11, 13, 15, 17, 19, 28, 29, and 30, and thick dust on the 1st with minimum visibility of ½ mile; as reported before Kansas had duststorms only a short time after heavy rains.

On the 13th the most severe duststorm of the month in Montana affected all of Sheridan, Daniels, Roosevelt, and Richland Counties, and eastern parts of McCone and Valley Counties; local storms occurred in northern Judith Basin and central Lincoln Counties. Duststorms were general in North Dakota on the 13th–16th and in central and western portions of that State on the 1st–2d; some western stations reported the storms of the 13th–15th the worst ever observed. No damage was caused by the duststorms in Oklahoma, where heavy dust was confined to the Panhandle counties. Visibility was reduced to 100 feet at times at Kenton, Cimarron County, on the 15th; on the 13th, the visibility was 400 feet.

June.—The month of June brought deficient precipitation to large areas from the Texas Panhandle northward; in portions of Nebraska and the Dakotas the deficiency amounted to 15 percent or more of normal. Portions of Texas, Oklahoma, and eastern Kansas had above-normal rains and the heavy rains of the preceding month were also beneficial in reducing both the extent, severity, and frequency of duststorms. None was reported east of the Mississippi. In the northern Great Plains local storms occurred in portions of Daniels and Sheridan Counties, Mont., on two dates, and light dust was general in North Dakota on the 6th. In South Dakota local storms were general in the eastern two-thirds on 4 days early in the month and in the western portion on the 27th. Visibility was reduced to ¼ mile at times at Moorhead, Minn., on the 6th, and light dust was reported at that station on two other dates early in the month. At Rock Springs, Wyo., on June 20, visibility was reduced to zero for half an hour and several storms with zero visibility were reported at Goodwell, Okla. The storm at Springfield, Mo., on the 14th was the worst reported in 2 years.

The following comment from the Colorado report is interesting:

> Duststorms during June have been less extensive and intensive due to large sections being "healed" over with weeds. There are large tracts of land, however, which will not grow weeds or any cover of vegetation and dust of considerable intensity continues in the lee of these fields with the slightest wind movement * * *. Duststorms reducing the visibility to from 100 feet to zero and lasting from 4 to 18 hours occurred in Baca County on the 8th, 12th, 13th, 15th, 18th, 27th, 28th, and 29th.

At Dodge City, Kans., the most severe duststorm of recent years occurred on the 10th. The visibility was reduced to 10 feet or less and windshields of cars driving against the storm were sandblasted to such an extent that new glass was required. At the time of the Dodge City report the center of the dust section was 50 to 60 miles west and south of Dodge City and the railroad was still using plows to enable them to move trains on the branch line from Dodge City to Boise City, Okla. In one of the cuts dust filled in 2 to 7 feet deep for a distance of 2,500 feet despite the fact that Kansas had from 2 to 4 or more inches of rain during the past month.

It is interesting to note that on June 5 a duststorm rivaling those of the United States' Dust Bowl struck the central part of Japan's Hokkaido Island. This storm covered 75,000 acres of valuable farm land with an inch of fine silt and inflicted crop losses estimated at 65 to 80 percent. Six factories and numerous dwellings were damaged heavily, schools had to be closed, and communication lines were put out of service.

July.—During July the extreme northern and extreme southern Great Plains and portions of Nebraska and South Dakota had above-normal rainfall; elsewhere in the Plains area subnormal precipitation occurred. Light dust was reported in central and southern Illinois on the 7th and 10th and local soil-blowing occurred in the eastern two-thirds of South Dakota on the 2d–4th, 11th, 13th, and 18th. No unusual duststorms occurred in Nebraska and the month was the first at Dodge City, Kans., without such storms since January 1937. Light storms were reported in western Kansas on about 5 days during the first half of the month. Light to moderate storms were reported at Waynoka, Okla., on the 13th, at Kenton on the 22d and at Tulsa on the 27th. Light dust was reported at Abilene, Tex., on the 7th.

Portions of Montana, particularly Valley, Chouteau, and Yellowstone Counties, had light storms on 1 or 2 days and a severe storm occurred in Gallatin County, but elsewhere there was little dust blowing or soil movement during the month in that State.

August.—August was similar to July, as only a few storms were reported and these were usually light and local in character, despite the fact that precipitation for the Great Plains as a whole was subnormal, particularly in much of Texas and Oklahoma and large portions of the Dakotas and Nebraska.

Light dust was reported in extreme western Minnesota on the 18th and local soil blowing occurred in all sections of South Dakota on the 1st–5th, 13th–20th, and 24th but with little or no damage. Light storms were reported in portions of McCone, Fergus, and Garfield Counties, Mont., on the 2d, 11th, and 29th and a few light local storms occurred in Nebraska on the 2d, 9th, 13th, 18th, and 19th. Only one was reported from Oklahoma; this was at Waynoka on the 20th and was unimportant. It was dusty on several days in Kansas, but only a few storms of local nature occurred in extreme northwestern and extreme southwestern portions; the soil in this State, particularly in the west, was still very dry at the close of the month.

September.—During September precipitation was much greater than normal over a wide belt extending from Lake Michigan southwestward to Colorado and northern New Mexico with from two to nearly four times the usual amounts for the month. Totals were subnormal in the extreme northern Great Plains and also in southern sections from eastern Kansas and extreme western Oklahoma southward. Despite these heavy rains and even larger percentages of normal in eastern sections, light dust was reported at Hartford, Conn., on several dates; this is the most eastern occurrence of dust during the year.

Light local duststorms occurred on 4 days during the last half of the month in South Dakota, on only 1 day in Nebraska, and there were a few local storms in Kansas, mostly in southwestern counties, on the 12th, 17th, and 28th; one of these storms was especially severe. A few local storms were reported in Oklahoma on the 14th, 17th, 27th, and 29th. The storm at Alva on the 17th reduced visibility to ¼ mile for an hour.

At Rock Springs, Wyo., a storm on the 30th caused occasional zero visibility during the afternoon, and severe duststorms were reported in the vicinity of Helena and Trident, Mont., on the 4th. On September 29 southerly winds of gale force caused considerable dust and soil blowing in the Missoula River and Flathead Valleys during the late afternoon. The storm began about 5 p. m. in central Missoula County and moved northward through Lake and eastern Sanders Counties to the upper end of the Flathead Valley; it lasted nearly an hour during which time traffic was at a standstill because of poor visibility.

October.—October was unusually dry in practically all central portions of the country; Kansas and Oklahoma had 17 percent of normal rainfall, Nebraska 11, South Dakota 12, North Dakota 51, Texas 32, Colorado 72, and New Mexico 91 percent; the total monthly fall for Minnesota was only 26 percent of normal. Despite these low monthly totals there were only a few duststorms and none of these compared in severity or extent with those in earlier months. In southern sections light local dust was reported on three dates in Oklahoma and on one date in Texas. Only light dust was reported in extreme western Minnesota and this only on the 6th, 10th, and 12th. No storms were reported in Kansas and only one light storm occurred in Nebraska; this was on the 8th. There were a few light and widely scattered storms at the beginning and near the end of the month in North Dakota. Local dust blowing was reported on the 1st, 10th–12th, 21st–25th, and 29th–30th in South Dakota; all of these storms were light; the one on the 25th was the most prominently mentioned. Light storms occurred in southern Rosebud County, Mont., on the 13th and in west-central Sheridan County on the 27th.

November.—Percentages of normal precipitation for November were much more favorable in the Plains area than during October. The lowest percentage reported in the northern Plains was 85 for South Dakota and in the southern sections 41 and 70 for New Mexico and Texas, respectively.

Duststorms of November were confined to Montana, Wyoming, South Dakota, Kansas, Oklahoma, and Texas, although there was one report of a heavy dust fall mixed with snow at Sault Ste. Marie, Mich. In Montana a light storm occurred in Judith Basin County on the 18th and dusty conditions prevailed at Rock Springs, Wyo., on the 4th with visibility reduced to zero at times. Light local dust blowing was reported in South Dakota on the 1st, 8th, and 21st, and at Dodge City, Kans., on the 1st, 2d, 9th, and 21st; the storm on the 21st covered three or four counties in the southwestern portion of the State. In Oklahoma dust was reported on the 2d and 21st at Waynoka; the only occurrence of heavy dust in this State was on the 21st when visibility at Alva was reduced to ½ mile. Light dust was reported at Abilene, Tex., on the 17th and 21st.

December.—The final month of 1938 brought above-normal precipitation to much of the Dust Bowl and nearly all the Plains States. The lowest percentage of normal was 88 in South Dakota and Texas. During December there was again a heavy fall of dust mixed with snow at Sault Ste. Marie, Mich., on the 7th and muddy rain fell on December 4 at Madison, Wis. Kansas City, Mo., reported dusty conditions on the 28th with a minimum visibility of 1¼ miles.

Light duststorms were reported in Montana on the 3d, 5th, 10th, 24th, and 25th; the storm of the 25th was severe in portions of central Big Horn County. Local dust blowing was reported in South Dakota on the 17th, 24th, and 26th, and from several stations in the eastern and western thirds of that State on the 25th. Heavy dust occurred at Dodge City, Kans., on the 4th with a visibility of ½ mile and light dust at Wichita on the 26th and 28th; rather severe storms occurred locally in the western third of the State on the 4th, 26th, and 27th. At Goodwell, Okla., the visibility was less than a mile on the 4th and dusty conditions were reported in the Panhandle on the 4th, 15th, 26th, 28th, 30th, and 31st; light dust occurred at Goodwell on about 10 days during December. In Texas only a few storms, mostly light, were reported; Abilene reported dusty conditions on the 4th, 5th, 16th, 26th, and 27th; while at Amarillo visibility was at times reduced to ¼ mile.

Occasional soil blowing was still being reported as the year closed, and until rainfall returns to normal, or a more permanent vegetative cover is secured, duststorms may be expected from time to time throughout the Great Plains area.

WEATHER OF 1938 IN THE UNITED STATES

By J. P. KOHLER

[Weather Bureau, Washington, D. C., February 1939]

The year 1938 averaged much warmer and slightly wetter than normal. Summations of temperatures over the country reveal that 1938 was one of the warmest years of record. The departure from normal temperature chart, herewith, shows that every first-order station in the United States had above-normal temperature for the year—a condition which probably is unparalleled in the Bureau's records. The excess temperature was largely the result of more or less steady warmth rather than periods of abnormally high temperatures which so strongly characterized the summers of 1934 and 1936, especially in the interior sections.

The greatest plus temperature departures occurred in the interior sections west and southwest of the Lake region over the Mississippi and Missouri Valleys and the Plains States. Notwithstanding the pronounced above-normal temperature trends, many western and northern sections experienced severe cold periods at times during January and February. Minimum temperatures in the northern Plains and northern portions of the Mississippi and Missouri Valleys during these months generally ranged from −35° to the lowest of record for the year, −51° at Long Lake, Wis., on February 1.

Table 1 gives, for the 42 climatic sections, monthly and annual departures of the mean temperature from the normal. This table shows that several States had slightly below-normal mean temperatures in January. The same is true of a few States in February; May and June were generally cool. However, in the remaining months of the year, departures were generally positive, and for the year, only 3 States, Arizona, California, and New Mexico, figured below normal and this by only slight amounts.

TABLE 1.—*Monthly and annual temperature departures from normal, for the year 1938*

Section	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Alabama	+1.7	+6.7	+7.9	+0.5	+1.6	−0.8	+0.1	+1.7	−4.0	+2.0	+1.2	+0.3	+1.6
Arizona	+2.7	−.5	−2.1	−.6	−1.0	−.3	−.9	+.1	+1.8	−.2	−4.5	+2.8	−.2
Arkansas	+1.1	+7.3	+7.7	+.6	+.9	−1.4	+1.5	+3.1	+1.3	+4.2	−.7	+1.0	+2.2
California	+1.6	−2.4	−3.9	−1.5	−.3	+.1	−.6	−.5	+2.0	−1.9	−3.2	+1.8	−.7
Colorado	+3.0	+3.2	+3.2	+1.2	−.3	+1.3	+.1	+2.9	+2.3	+3.3	−4.6	+1.7	+1.4
Florida	−.6	+2.9	+4.1	+.4	+1.2	−1.0	−1.1	+.8	−.7	−2.3	+2.1	−1.1	+.4
Georgia	+.3	+6.1	+5.6	+.3	+1.2	−2.0	−1.3	+1.8	−.6	−.4	+2.6	−1.6	+1.0
Idaho	+3.8	+3.3	−.2	+.5	−1.2	+1.8	+.1	−.9	+6.2	+1.4	−5.6	+2.6	+1.0
Illinois	+.8	+9.3	+8.4	+2.0	+.3	−1.4	+.6	+3.1	+1.2	+4.7	+2.7	+1.0	+2.7
Indiana	+.5	+8.7	+7.1	+2.6	+.4	−1.6	−.1	+2.7	+1.0	+3.5	+2.9	+.8	+2.4
Iowa	+2.5	+6.7	+9.2	+1.6	−.5	−.3	+1.9	+3.5	+3.0	+7.8	+1.4	+2.3	+3.3
Kansas	+4.9	+4.7	+7.4	+.3	−.3	.0	+1.8	+5.1	+2.6	+7.7	−.6	+3.2	+3.1
Kentucky	−.1	+8.6	+7.3	+3.1	+.3	−2.0	.0	+2.2	−.2	+1.7	+1.4	+.2	+1.9
Louisiana	+.9	+5.3	+6.7	−.9	+.7	−.3	+.1	+.6	−.8	+1.4	−1.0	−.1	+1.0
Maryland-Delaware	−.1	+5.3	+4.5	+3.0	−1.1	−.6	+.6	+3.0	−1.9	+.6	+2.9	+.8	+1.4
Michigan	−1.5	+5.3	+6.6	+1.8	+.8	−.5	+.3	+4.2	−1.9	+3.6	+2.2	+1.4	+1.9
Minnesota	−.5	+3.7	+8.2	+.7	−1.8	.0	+.3	+3.9	+1.5	+6.5	−1.8	+1.9	+1.9
Mississippi	+.7	+6.6	+7.7	−.3	+1.5	−1.1	+.9	+1.9	+.2	+1.8	+.1	−.7	+1.6
Missouri	+2.3	+8.3	+9.6	+1.5	+.6	−1.2	+1.7	+4.6	+2.3	+6.4	+1.5	+1.8	+3.3
Montana	+5.2	−3.8	+2.2	+.4	−1.2	+1.6	+.4	+.2	+7.5	+2.8	−3.2	+3.4	+1.3
Nebraska	+5.1	+2.4	+6.6	+1.1	−.9	+1.4	+1.8	+4.7	+3.2	+7.7	−1.3	+3.3	+2.9
Nevada	+5.8	+.9	−2.0	+1.4	−.1	+1.0	.0	+.7	+4.8	+.9	−4.4	+4.2	+1.1
New England	−1.3	+3.4	+1.9	+2.6	−1.5	+1.5	+.6	+3.3	−2.3	+3.0	+2.6	+2.1	+1.3
New Jersey	+.1	+4.8	+4.1	+3.3	−1.4	−1.6	+1.0	+3.6	−2.3	+1.5	+2.0	+1.1	+1.4
New Mexico	+.5	+1.0	+1.0	−.4	−1.1	−.5	−1.5	+1.2	−.7	+.9	−4.0	+2.0	−.1
New York	−.9	+5.1	+4.9	+2.4	−.9	+.5	+1.1	+3.7	−3.6	+2.4	+2.7	+2.1	+1.6
North Carolina	−.6	+5.3	+5.5	+1.7	+.9	−1.8	−1.2	+1.9	−.2	−.4	+2.9	−.5	+1.1
North Dakota	+3.4	−2.4	+9.3	+1.4	−1.4	+1.1	+.9	+3.4	+5.1	+7.1	−2.8	+5.5	+2.6
Ohio	+1.5	+8.1	+7.3	+3.0	+.8	−1.0	+.5	+3.2	+.1	+2.4	+2.6	+1.3	+2.5
Oklahoma	+3.9	+5.4	+7.3	−.9	+.5	−.3	+.5	+2.9	+1.4	+5.5	−1.0	+2.3	+2.3
Oregon	+3.0	.0	−2.2	+.2	−.1	+1.7	+1.6	−1.8	+4.2	+.3	−4.2	+1.7	+.4
Pennsylvania	+.4	+5.8	+5.0	+2.7	−.7	−1.0	+1.0	+3.5	−2.2	+2.2	+1.4	+.9	+1.6
South Carolina	−.4	+5.3	+5.6	+.5	+1.4	−1.9	−1.6	+2.4	.0	−.7	+3.0	−.6	+1.1
South Dakota	+2.9	−.5	+6.7	+1.6	−1.1	+1.9	+1.6	+5.0	+3.9	+7.4	−2.4	+4.1	+2.6
Tennessee	+.4	+7.9	+7.3	+1.7	+.9	−2.1	+.5	+2.5	−.4	+2.1	+1.1	−.3	+1.8
Texas	+2.0	+4.3	+5.7	−1.6	+.5	+.4	−.1	+.8	+.4	+2.9	−2.2	+1.4	+1.2
Utah	+4.0	+3.1	−.6	+1.0	−2.0	+1.0	+1.7	+.6	+3.5	+1.2	−6.9	+4.0	+1.0
Virginia	−.3	+5.8	+5.1	+2.4	−.4	−1.6	.0	+2.0	−1.1	−.2	+2.8	.0	+1.2
Washington	+3.4	+.8	−.5	+1.2	+.7	+2.4	+2.9	−1.8	+5.9	+1.4	−2.9	+1.6	+1.3
West Virginia	+.7	+7.6	+5.8	+3.0	−.6	−1.7	+.4	+1.9	−.6	+.4	+1.5	+.1	+1.5
Wisconsin	.0	+6.5	+6.8	+1.8	−.1	−.6	.0	+3.2	−.7	+4.8	+1.2	+.7	+2.0
Wyoming	+2.3	+2.4	+2.7	+1.1	−1.0	+1.5	−.6	+1.1	+4.3	+4.0	−5.9	+2.2	+1.2

Recent studies[1] indicate that the tendency to higher temperatures which set in about 1900 has been definitely outstanding in the last decade. Temperature records for the past 20 years show 1929 as the only year appreciably cooler than normal, for the country as a whole; 1919 and 1924 were slightly below normal. The remaining years had above-normal warmth.

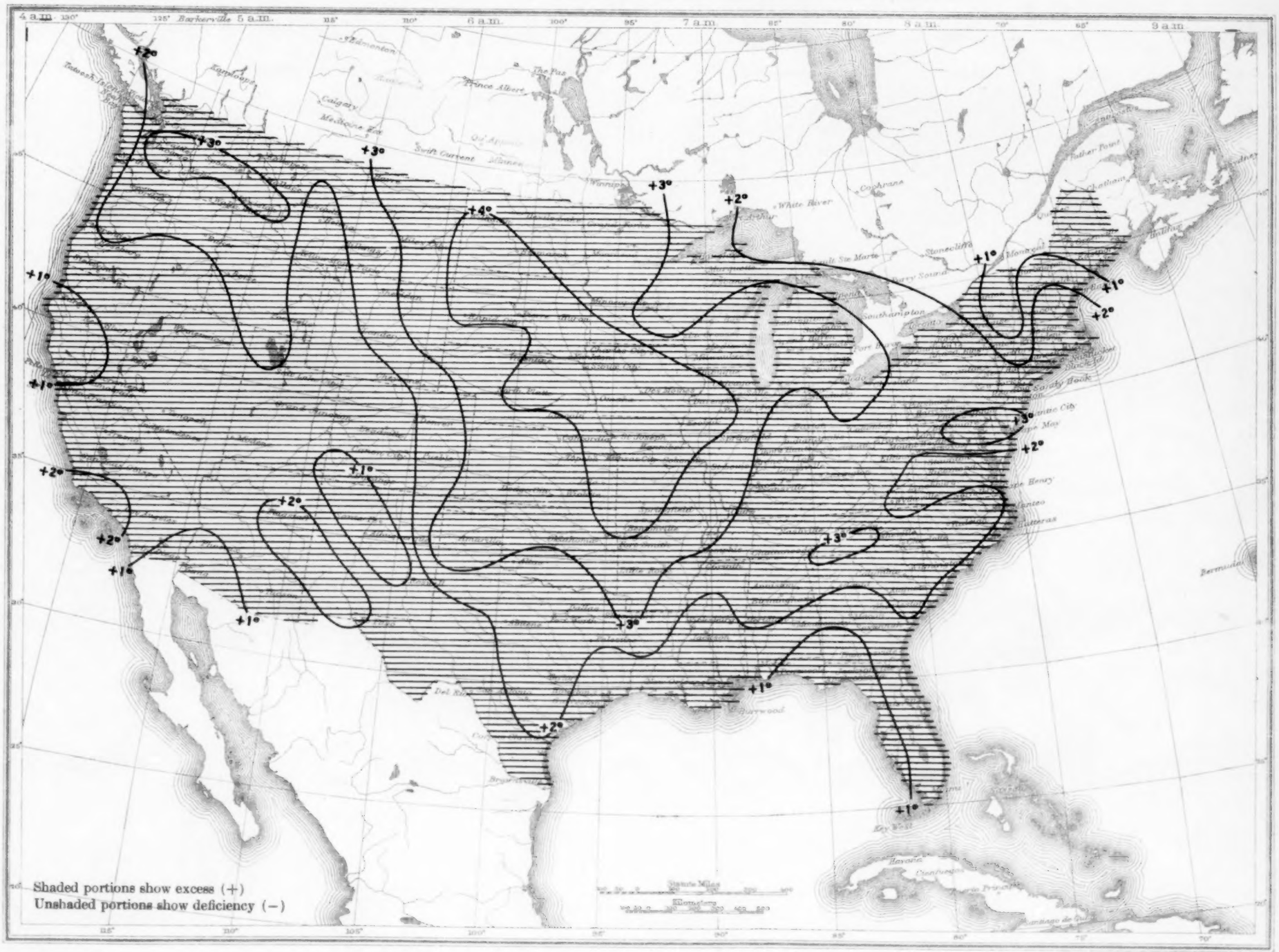
Precipitation during 1938, while slightly above normal for the year, was generally much above the average in the first half of the year, and deficient in the last half in some midwestern States, especially in the north and central portions of the Great Plains. The average for the year was 29.47 inches, about 1 percent above normal. In 1937, rainfall averaged 30.34 inches; 27.14 inches in 1936; 29.34 inches in 1935, and 25.95 inches in 1934. Since the normal is 29.11 inches, the last 2 years have had above-normal rainfall.

Table 2 shows the monthly and annual distribution of precipitation in percent of normal for the 42 climatic sections. For the year, as a whole, most States had above-normal rainfall. The South Atlantic and Gulf States and

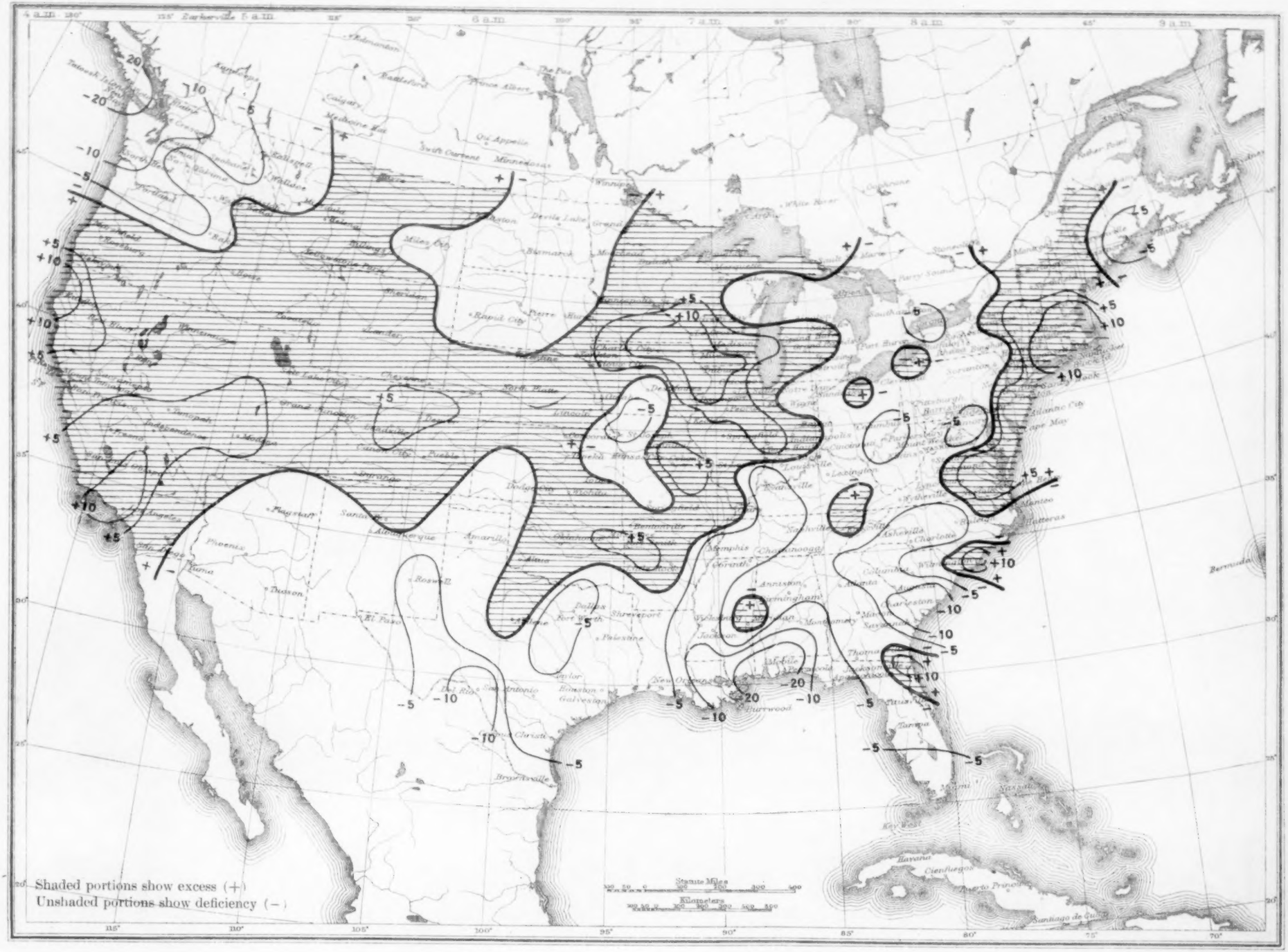
[1] From notes by J. B. Kincer, U. S. Weather Bureau, Washington, D. C.

Annual Temperature Departures (°F.) in the United States, 1938

Annual Temperature Departures (°F.) in the United States, 1938



Annual Precipitation Departures (inches) in the United States, 1938



the northern Great Plains were relatively dry, but all others, except locally, had above-normal rainfall. Colorado, Nevada, Wisconsin, Utah and the New England sections had considerable in excess of the usual annual amount.

The annual precipitation departure chart, herewith, is constructed from data furnished by nearly 200 first-order Weather Bureau stations, and gives some idea of the local variations in the yearly rainfall. The greatest positive departures prevailed in the upper Mississippi Valley, and along the New England and North Atlantic coasts, while in the Gulf and Southeastern States, the Dakotas, and the extreme Northwest, deficiencies ranging from 1 inch to more than 20 inches at some stations along the east Gulf coast.

Temperature extremes during the year were well within the limits of previous records. The highest maximum reported was 125° at Cow Creek, Calif., on several days during July and August. The lowest temperature reported was −51° at Long Lake, Wis., on February 1. Temperatures of freezing or below occurred in every State sometime during the 12 months; and during the summer months of June, July, and August minima of 16° to 22° were noted in several western Mountain States. The lowest temperature recorded in Alaska during the year was 64° below zero in February at Fort Yukon.

The greast monthly amount of precipitation reported from any station in the United States was 38.05 inches at Inskip, Calif., during February. By way of contrast, one station in Hawaii received 98.78 inches during April.

TABLE 2.—*Percentage of Normal Precipitation, 1938*

Section	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Alabama	69	36	107	223	89	105	139	68	43	12	102	64	98
Arizona	59	145	229	42	69	296	73	93	76	14	7	183	101
Arkansas	151	183	126	99	91	106	99	62	46	30	145	60	102
California	77	220	232	121	42	59	214	80	80	131	47	76	128
Colorado	108	102	167	115	130	121	75	90	228	74	116	99	117
Florida	75	44	60	46	101	101	117	54	86	111	74	50	82
Georgia	49	23	76	101	100	126	132	58	74	26	100	63	85
Idaho	86	110	195	106	94	116	187	85	55	186	94	74	113
Illinois	112	112	183	92	124	128	144	99	86	50	85	73	109
Indiana	56	117	168	74	136	134	157	95	86	31	98	59	104
Iowa	107	87	136	134	133	100	114	108	149	37	170	60	115
Kansas	68	115	143	93	201	102	90	80	78	17	107	24	102
Kentucky	82	69	134	72	142	94	176	119	119	17	106	47	101
Louisiana	103	70	79	152	55	99	100	123	73	41	104	65	90
Maryland-Delaware	72	82	79	50	127	105	173	63	189	68	107	89	101
Michigan	135	190	127	63	118	100	93	162	85	43	66	104	103
Minnesota	80	107	127	151	207	84	98	81	126	26	162	78	113
Mississippi	97	65	104	174	61	126	107	93	46	32	91	66	92
Missouri	132	160	157	95	127	99	93	67	45	42	165	90	102
Montana	68	99	132	62	145	123	141	81	64	170	91	64	109
Nebraska	64	89	129	123	141	70	97	70	134	11	92	26	95
Nevada	63	178	215	162	134	220	211	82	39	236	80	43	134
New England	121	76	71	87	109	162	208	92	247	68	88	118	122
New Jersey	102	64	57	78	94	210	185	65	272	72	108	77	116
New Mexico	102	135	113	56	58	186	90	41	205	96	41	110	101
New York	100	112	81	87	86	100	129	115	221	40	92	100	106
North Carolina	79	39	78	123	118	131	133	51	147	40	152	84	97
North Dakota	102	148	78	75	109	80	134	72	40	52	140	62	89
Ohio	54	111	157	102	142	108	131	92	134	27	116	50	105
Oklahoma	99	330	193	85	126	114	88	68	60	17	108	37	101
Oregon	89	148	195	94	48	74	113	31	71	107	90	65	101
Pennsylvania	77	96	93	83	99	123	112	70	137	56	108	81	95
South Carolina	42	22	57	207	114	101	119	40	120	36	122	76	85
South Dakota	95	105	110	114	117	77	78	49	140	12	85	46	88
Tennessee	114	57	104	105	140	116	144	105	89	20	121	55	100
Texas	146	116	102	110	83	102	131	55	54	33	66	76	88
Utah	76	117	208	91	148	123	76	104	76	162	122	91	118
Virginia	86	53	81	78	113	151	160	60	127	42	157	92	101
Washington	71	91	136	100	55	48	55	45	51	120	77	83	84
West Virginia	61	96	103	87	149	132	122	63	122	32	143	54	99
Wisconsin	171	185	146	121	141	127	122	155	199	54	128	96	137
Wyoming	101	67	112	101	124	95	131	97	111	107	144	92	109

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By AMY P. LESHER

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SOLAR OBSERVATIONS

[Meteorological Research Division, EDGAR W. WOOLARD in charge]

SOLAR RADIATION OBSERVATIONS, JANUARY 1939

By IRVING F. HAND

Measurements of solar radiant energy received at the surface of the earth are made at eight stations maintained by the Weather Bureau, and at nine cooperating stations maintained by other institutions. The intensity of the total radiation from sun and sky on a horizontal surface is continuously recorded (from sunrise to sunset) at all these stations by self-registering instruments; pyrheliometric measurements of the intensity of direct solar radiation at normal incidence are made at frequent intervals on clear days at three Weather Bureau stations (Washington, D. C., Madison, Wis., Lincoln, Nebr.) and at the Blue Hill Observatory of Harvard University. Occasional observations of sky polarization are taken at the Weather Bureau stations at Washington and Madison.

The geographic coordinates of the stations, and descriptions of the instrumental equipment, station exposures, and methods of observation, together with summaries of the data, obtained up to the end of 1936, will be found in the MONTHLY WEATHER REVIEW, December 1937, pp. 415 to 441; further descriptions of instruments and methods are given in Weather Bureau Circular Q.

Table 1 contains the measurements of the intensity of direct solar radiation at normal incidence, with means and their departures from normal (means based on less than 3 values are in parentheses). At Madison and Lincoln the observations are made with the Marvin pyrheliometer; at Washington and Blue Hill they are obtained with a recording thermopile, checked by observations with a Marvin pyrheliometer at Washington and with a Smithsonian silver disk pyrheliometer at Blue Hill. The table also gives vapor pressures at 8 a. m. (75th meridian time) and at noon (local mean solar time).

Table 2 contains the average amounts of radiation received daily on a horizontal surface from both sun and sky during each week, their departures from normal and the accumulated departures since the beginning of the year. The values at most of the stations are obtained from the records of the Eppley pyrheliometer recording on either a microammeter or a potentiometer.

Direct radiation intensities averaged close to normal for January at Washington and Lincoln and above normal at Madison and Blue Hill.

Total solar and sky radiation was below normal for all stations for which normals have been computed with the exception of Washington, New York, La Jolla, New Orleans, Blue Hill, and San Juan. Beginning with this issue of the REVIEW departures from normal for Newport will be included in table 2.

No polarization measurements were made during January owing to snow and ice cover.

TABLE 1.—*Solar radiation intensities during January 1939*

[Gram-calories per minute per square centimeter of normal surface]

WASHINGTON, D. C.

Date	Sun's zenith distance: 8 a. m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
	75th mer. time	Air mass: A. M.					P. M.				Local mean solar time
	e	5.0	4.0	3.0	2.0	[1] 1.0	2.0	3.0	4.0	5.0	e
	mm.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
Jan. 6	4.75	0.76	0.90		1.21						4.95
Jan. 7	5.36	.62	.77	0.96							5.36
Jan. 16	4.17							0.94			2.45
Jan. 17	2.87				1.21						2.36
Jan. 23	1.52	.75	.88	1.22	1.40		1.39				1.52
Means		.75	(.85)	(1.08)	1.27		(1.39)	(.94)			
Departures		−.63	−.01	+.06	+.03		+.14	−.10			

MADISON, WIS.

Jan. 27	2.26	1.07	1.16								2.26
Jan. 31	1.45	1.11			1.46						1.60
Means		(1.09)	(1.16)		(1.46)						
Departures		+.14	+.10		+.10						

LINCOLN, NEBR.

Jan. 5	2.74	1.10	1.23	1.37				1.39	1.26	1.15	2.87
Jan. 11	3.15	.58	.98	1.26				1.29	1.15	1.06	3.81
Jan. 17	2.36	.66	.89	1.16							2.74
Jan. 18	1.96	.87	1.00	1.16					.79	.70	2.16
Jan. 19	1.60							1.21	1.01	.91	3.81
Jan. 20	3.30	.78	.91								3.45
Jan. 22	1.32							1.35	1.15	1.07	.91
Jan. 25	2.26				1.45			1.25			3.45
Jan. 26	2.06	1.17	1.26	1.38	1.53			1.35	1.21	1.09	2.36
Jan. 28	3.30	.79	.90	1.04							4.57
Means		.85	1.02	1.23	(1.49)			1.31	1.10	1.00	
Departures		−.08	−.03	+.03	+.10			+.12	+.05	+.07	

BLUE HILL, MASS.

Jan. 8	4.4						1.13	1.08	0.96	0.86	3.5
Jan. 9	2.4						1.24				3.2
Jan. 10	4.8							.89	.68	.51	6.8
Jan. 11	3.5								1.12	.96	3.0
Jan. 12	2.3	1.03	1.13	1.23							1.7
Jan. 15	1.1	1.12	1.23	1.34	1.48			1.30	1.23	1.07	1.2
Jan. 17	2.4	.94	1.11	1.28	1.39						1.6
Jan. 23	.3	1.14	1.24	1.33	1.45		1.45	1.26	1.13	1.03	.8
Jan. 26	.3	1.12	1.20	1.30	1.40		1.44		1.07	.98	.6
Jan. 27	.4			1.26	1.44		1.42	1.27	1.15	1.04	.8
Jan. 28	1.1	.94	1.06	1.19	1.34						1.7
Means		1.05	1.16	1.28	1.42		1.34	1.16	1.05	.92	
Departures		+.06	+.12	+.13	+.11		+.02	−.01	.00	−.01	

[1] Extrapolated.

TABLE 2.—*Average daily totals of solar radiation (direct+diffuse) received on a horizontal surface*

Week beginning—	Washington	Madison	Lincoln	Chicago	New York	Fresno	Fairbanks	Twin Falls	La Jolla	Miami	New Orleans	Riverside	Blue Hill	San Juan	Friday Harbor	Ithaca	Newport
	Gram-calories per square centimeter																
	cal.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
Jan. 1	175	86	179	81	99	159	8	113	246		277	226	110	457		68	120
Jan. 8	168	108	151	60	127	217	9	135	279		215	263	175	507		58	177
Jan. 15	174	128	200	59	129	147	12	121	213		270	230	184	485		140	191
Jan. 22	202	179	227	123	158	172	21	169	320		208	291	200	490		141	202
	Departures of daily total from normals																
Jan. 1	+7	−40	+4	−1	−5	+10	+1	−43	−2		+102	−57	−23	+63		−18	−14
Jan. 8	+18	−24	−32	−21	+18	+54	−1	−24	+30		+13	−6	+20	+83		−19	+9
Jan. 15	+19	−23	+6	−35	+17	−43	−1	−51	−31		+58	−83	+17	+45		+34	−1
Jan. 22	+26	−5	−2	+5	+7	−50	−7	−17	+49		+10	+5	+10	+46		−2	+1
	Accumulated departures since Jan. 1, 1939																
	+490	−644	−168	−364	+259	−203	−56	−945	+322		+1,281	−987	+168	+1,659		−35	−35

POSITIONS AND AREAS OF SUN SPOTS

Communicated by Capt. J. F. Hellweg, U. S. Navy (Ret.) Superintendent, U. S. Naval Observatory. Data from measurements at the U. S. Naval Observatory from plates obtained at the observatories indicated. Difference in longitude is measured from the central meridian, positive toward the west. Latitude is positive toward the north. Areas are corrected for foreshortening and expressed in millionths of Sun's visible hemisphere. For each day, below longitude, latitude, area of spot or group, and spot count, are given respectively the assumed longitude of the center of the disk, assumed latitude of the center of the disk, total area of spots and groups, and total spot count]

Date	Eastern standard time	Mount Wilson group No.	Heliographic: Difference in longitude	Heliographic: Longitude	Heliographic: Latitude	Heliographic: Distance from center of disk	Area of spot or group	Spot count	Plate quality [1]	Observatory
1939	h. m.		°	°	°	°				
Jan. 1....	13 3	6259	−71	236	−16	71	48	4	G	U. S. Naval.
		6260	−66	241	−7	66	6	2		
		6259	−63	244	−16	63	145	4		
		6258	−39	268	−11	40	485	8		
		6261	−13	294	−2	13	6	2		
		6254	+33	340	−1	33	230	5		
		6252	+85	32	+15	86	12	1		
				(307)	(−3)		932	26		
Jan. 2....	11 23	6262	−70	225	+21	74	16	4	VG	Do.
		6259	−59	236	−16	58	73	5		
		6260	−52	243	−7	51	12	2		
		6259	−49	246	−16	50	109	5		
		6258	−27	268	−11	28	533	9		
		6254	+40	335	+2	41	12	3		
		6254	+46	341	−1	46	121	2		
				(295)	(−3)		876	30		
Jan. 3....	10 58	6262	−58	224	+21	61	24	3	F	Do.
		6265	−51	231	−12	52	6	1		
		6259	−46	236	−17	48	73	8		
		6260	−30	243	−7	39	16	1		
		6259	−37	245	−17	39	85	4		
		6258	−13	269	−11	16	485	14		
		6264	+9	291	+19	24	85	13		
		6263	+53	335	+13	55	36	1		
		6254	+60	342	−1	60	121	2		
				(282)	(−3)		931	47		
Jan. 4....	11 12	6259	−32	237	−17	34	218	24	VG	Do.
		6260	−24	245	−7	25	12	3		
		6259	−22	247	−17	25	97	6		
		6258	0	269	−11	8	630	23		
		6266	+18	287	−19	23	6	1		
		6264	+22	291	+20	31	121	18		
		6263	+67	336	+13	68	12	2		
		6254	+74	343	−1	74	121	1		
				(269)	(−3)		1,217	78		
Jan. 6....	11 20	6269	−70	172	−10	70	158	2	G	Do.
		6268	−64	178	+32	70	85	8		
		6267	−61	181	+11	62	48	2		
		6259	−7	235	−18	8	121	18		
		(1)	−5	237	−10	8	36	3		
		6259	+3	245	−18	15	73	7		
		6258	+27	269	−12	28	436	3		
		6264	+50	292	+20	55	388	24		
				(242)	(−4)		1,345	67		
Jan. 7....	11 3	6269	−58	171	−10	58	194	2	F	Do.
		6268	−50	179	+32	60	291	5		
		6267	−48	181	+10	50	48	2		
		6270	−17	212	−24	26	24	2		
		6259	+7	236	−18	16	73	6		
		6259	+15	244	−18	20	73	4		
		6258	+39	268	−12	40	485	4		
		6264	+63	292	+20	67	291	16		
				(229)	(−4)		1,479	41		
Jan. 8....	11 36	6269	−44	172	−11	45	194	1	F	Do.
		6268	−30	177	+31	51	388	15		
		6267	−34	182	+10	36	12	1		
		6270	−2	214	−23	20	73	8		
		6265	+16	232	−15	20	24	3		
		6259	+22	238	−17	25	24	2		
		6259	+30	246	−17	32	48	1		
		6258	+54	270	−11	55	436	1		
		6264	+79	295	+20	80	6	2		
				(216)	(−4)		1,205	34		
Jan. 9....	11 17	6272	−84	119	+10	84	194	3	F	Do.
		6271	−84	119	−8	84	97	1		
		6271	−70	133	−9	70	24	1		
		6269	−30	173	−11	31	145	1		
		6268	−24	179	+31	41	339	18		
		6265	−4	199	−16	13	12	6		
		6270	+11	214	−23	22	48	10		
		6259	+36	239	−18	39	24	4		
		6259	+43	246	−18	45	48	4		
		6258	+68	271	−11	68	436	1		
				(203)	(−4)		1,367	49		

POSITIONS AND AREAS OF SUN SPOTS—Continued

Date	Eastern standard time	Mount Wilson group No.	Heliographic: Difference in longitude	Heliographic: Longitude	Heliographic: Latitude	Heliographic: Distance from center of disk	Area of spot or group	Spot count	Plate quality [1]	Observatory
1939	h. m.		°	°	°	°				
Jan. 10....	10 56	6271	−70	120	−9	70	145	5	VP	Mount Wilson.
		6272	−69	121	+9	70	291	3		
		6277	−69	121	+19	71	145	2		
		6276	−49	141	+11	51	61	2		
		6275	−48	142	−21	50	97	5		
		6269	−16	174	−11	18	145	3		
		6268	−11	179	+31	36	291	9		
		6274	+8	198	−9	10	97	4		
		6273	+10	200	−18	18	291	10		
		6270	+23	213	−23	30	48	2		
		6259	+49	239	−18	50	73	1		
		6258	+83	273	−12	83	436	2		
				(190)	(−4)		1,829	48		
Jan. 11....	12 11	6272	−57	119	+10	59	388	7	F	U. S. Naval.
		6277	−57	119	+21	61	97	5		
		6271	−54	122	−8	54	97	11		
		6276	−38	138	+12	41	73	7		
		6275	−33	143	−22	38	97	16		
		6278	−6	170	+11	15	6	1		
		6269	−3	173	−10	7	121	1		
		6268	+3	179	+31	35	145	12		
		6274	+23	199	−9	24	73	9		
		6273	+27	203	−16	29	388	20		
		6270	+40	216	−22	43	48	5		
				(176)	(−4)		1,533	94		
Jan. 12....	12 42	6277	−43	119	+20	49	97	8	F	Do
		6272	−42	120	+10	45	291	4		
		6271	−40	122	−9	40	73	9		
		6276	−21	141	+14	27	24	2		
		6275	−20	142	−21	26	218	15		
		6278	+8	170	+10	16	12	2		
		6269	+10	172	−10	12	170	2		
		6268	+18	180	+32	39	145	8		
		6279	+20	182	−29	32	12	2		
		6273	+35	197	−15	36	97	6		
		6274	+36	198	−8	37	36	4		
		6273	+41	203	−15	42	291	6		
		6270	+51	213	−21	52	12	2		
				(162)	(−4)		1,478	70		
Jan. 13....	11 28	6272	−29	121	+9	32	242	2	F	Mount Wilson.
		6277	−29	121	+19	37	97	8		
		6271	−27	123	−8	28	73	12		
		6276	−17	133	+12	22	24	4		
		6275	−7	143	−21	18	388	35		
		6269	+23	173	−11	25	97	3		
		6268	+31	181	+31	46	73	7		
		6274	+49	199	−9	49	36	2		
		6273	+57	207	−17	58	194	3		
				(150)	(−4)		1,224	76		
Jan. 14....	10 58	6272	−16	121	+10	22	291	16	P	U. S. Naval.
		6277	−15	122	+20	29	97	14		
		6275	+7	144	−20	17	436	37		
		6269	+36	173	−11	37	170	1		
		6280	+42	179	+26	50	109	9		
		6268	+42	179	+30	54	61	5		
		6273	+69	206	−17	70	242	1		
				(137)	(−4)		1,406	83		
Jan. 15....	11 50	6281	−77	46	+10	78	242	2	P	Mount Wilson.
		6271	−3	120	−8	5	24	7		
		6272	−2	121	+10	15	291	10		
		6277	−1	122	+20	25	97	8		
		6275	+20	143	−21	25	582	20		
		6276	+20	143	+13	27	12	2		
		6269	+50	173	−13	51	145	1		
		6268	+56	179	+29	64	36	2		
		6280	+57	180	+26	63	145	10		
		6273	+83	206	−17	83	194	2		
				(123)	(−5)		1,768	64		
Jan. 16....	12 25	6281	−63	47	+10	65	242	6	P	U. S. Naval.
		6282	−14	96	+23	31	12	4		
		6277	+7	117	+24	13	6	1		
		6277	+11	121	+21	18	48	9		
		6272	+11	121	+11	18	218	5		
		6275	+35	145	−19	38	242	25		
		6269	+62	172	−11	62	145	2		
		6280	+69	179	+28	73	97	2		
		6268	+70	180	+30	76	12	2		
				(110)	(−5)		1,022	56		

[1] Plate quality: VG=very good; G=good; F=fair; P=poor; VP=very poor.
[2] Not numbered.

POSITIONS AND AREAS OF SUN SPOTS—Continued

Date	Eastern standard time	Mount Wilson group No.	Heliographic: Difference in longitude	Heliographic: Longitude	Heliographic: Latitude	Heliographic: Distance from center of disk	Area of spot or group	Spot count	Plate quality [1]	Observatory
1939	h. m.		°	°	°	°				
Jan. 17...	12 26	6285	−67	30	−18	68	12	3	P	U. S. Naval.
		6281	−50	47	+10	52	242	8		
		6284	+7	104	+27	31	6	2		
		6277	+24	121	+20	35	61	5		
		6272	+25	122	+10	29	194	8		
		6282	+34	131	−21	37	12	6		
		6275	+48	145	−20	50	194	17		
		6269	+75	172	−11	75	145	2		
				(97)	(−5)		866	51		
Jan. 18...	12 11	6285	−54	30	−17	55	36	2	F	Mount Wilson.
		6281	−36	48	+7	38	194	8		
		6281	−29	55	+5	31	36	5		
		6277	+9	93	+20	26	73	6		
		6284	+21	105	+28	38	24	3		
		6272	+39	123	+9	42	194	1		
		6275	+60	144	−21	61	145	1		
		6275	+68	152	−18	69	48	9		
				(84)	(−5)		750	35		
Jan. 19...	11 52	6287	−80	351	−6	80	97	1	P	U. S. Naval.
		6285	−42	31	−18	42	16	1		
		6281	−22	49	+10	27	145	4		
		6281	−17	54	+7	20	48	1		
		6277	+50	121	+21	55	73	6		
		6272	+51	122	+9	53	145	1		
		6275	+70	141	−21	71	36	2		
				(71)	(−5)		560	16		
Jan. 21...	11 47	6290	−70	334	−8	70	242	6	VP	Do.
		6287	−59	345	−9	59	24	3		
		6287	−50	354	−8	50	73	4		
		6289	−33	11	−12	34	97	6		
		6288	+1	45	−18	14	97	4		
		6281	+5	49	+10	15	194	2		
		[2]	+60	104	+30	67	194	4		
		6272	+78	122	+9	79	194	1		
				(44)	(−5)		1,115	30		
Jan. 22...	12 43	6290	−57	334	−7	57	339	5	P	Do.
		6287	−43	348	−7	43	24	1		
		6287	−35	356	−6	35	73	2		
		6286	−35	356	−9	35	145	10		
		6289	−20	11	−12	21	145	5		
		6285	0	31	−20	16	97	6		
		6288	+13	44	−19	20	48	1		
		6288	+13	44	−6	13	24	1		
		6281	+18	49	+11	25	145	1		
				(31)	(−5)		1,040	32		
Jan. 23...	11 29	6291	−80	298	+15	21	194	2	P	Do.
		6290	−43	335	−7	43	339	8		
		6287	−23	355	−6	23	61	1		
		6286	−22	356	−9	23	145	15		
		6289	−7	11	−12	10	121	3		
		6285	+14	32	−19	20	12	3		
		6288	+26	44	−19	22	36	2		
		6281	+31	49	+10	35	121	3		
				(19)	(−5)		1,029	42		
Jan. 24...	13 54	6291	−78	286	+16	80	97	2	P	Do.
		6291	−68	296	+16	70	170	2		
		6290	−29	335	−8	29	364	15		
		6287	−9	355	−6	9	48	4		
		6286	−8	356	−9	10	97	13		
		6289	+8	12	−11	10	145	6		
		6281	+47	51	+8	49	315	14		
				(4)	(−5)		1,236	56		
Jan. 25...	11 54	6293	−82	270	−12	82	194	1	VP	Do.
		6291	−63	289	+15	67	73	1		
		6291	−54	298	+15	58	145	2		
		6290	−17	335	−9	17	339	11		
		6287	+3	355	−7	3	48	2		
		6286	+7	359	−10	8	48	4		
		6289	+19	11	−11	20	61	2		
		6281	+59	51	+9	60	291	10		
				(352)	(−5)		1,199	33		

[1] Plate quality: VG=very good; G=good; F=fair; P=poor; VP=very poor.
[2] Not numbered.

POSITIONS AND AREAS OF SUN SPOTS—Continued

Date	Eastern standard time	Mount Wilson group No.	Heliographic: Difference in longitude	Heliographic: Longitude	Heliographic: Latitude	Heliographic: Distance from center of disk	Area of spot or group	Spot count	Plate quality	Observatory
1939	h. m.		°	°	°	°				
Jan. 26...	10 55	6293	−72	267	−12	72	485	12	G	Mount Wilson.
		6291	−50	289	+15	55	97	2		
		6291	−41	298	+15	46	145	3		
		6292	−18	321	−14	20	48	6		
		6294	−8	331	−19	16	73	9		
		6290	−3	336	−10	5	388	25		
		6287	+14	353	−7	14	121	9		
		6286	+23	2	−10	24	97	5		
		6289	+28	7	−13	29	61	4		
		6281	+73	52	+9	75	291	15		
				(339)	(−6)		1,806	90		
Jan. 27...	11 31	6293	−59	267	−12	59	388	6	VP	U. S. Naval.
		6291	−37	289	+15	42	73	2		
		6291	−28	298	+16	36	97	2		
		6292	−5	321	−13	9	97	6		
		6294	+5	331	−17	12	121	7		
		6290	+9	335	−10	10	291	5		
		6287	+29	355	−5	29	73	4		
		6286	+38	4	−9	38	61	4		
		6289	+41	7	−11	42	73	4		
		6281	+87	53	+8	87	48	1		
				(326)	(−6)		1,322	41		
Jan. 28...	10 45	6295	−60	253	+7	61	6	1	P	Do.
		6293	−45	268	−12	46	388	7		
		6291	−23	290	+14	30	73	1		
		6291	−16	297	+15	26	145	1		
		6292	+7	320	−13	10	6	2		
		6294	+21	334	−17	24	48	4		
		6290	+23	336	−9	23	339	5		
		6286	+50	3	−9	50	6	1		
		6289	+55	8	−11	55	6	1		
				(313)	(−6)		1,017	23		
Jan. 31...	11 25	6298	−69	204	−17	69	85	2	F	Do.
		6296	−36	237	−12	37	12	2		
		6293	−6	267	−12	8	679	40		
		6291	+16	289	+15	26	61	4		
		6291	+24	297	+16	31	121	1		
		6292	+49	322	−15	50	24	2		
		6290	+63	336	−9	63	315	7		
				(273)	(−6)		1,297	58		

Mean daily area for 27 days=1,213.

PROVISIONAL SUNSPOT NUMBERS FOR JANUARY 1939

[Dependent alone on observations at Zurich, Switzerland]

[Data furnished through the courtesy of Prof. W. Brunner, Eidgen. Sternwarte, Zurich Switzerland]

January 1939	Relative numbers	January 1939	Relative numbers	January 1939	Relative numbers
1	41	11	*aa* 118	21	*Eacd* 86
2	----------	12	111	22	83
3	----------	13	103	23	77
4	*Mac* 76	14	*a* 84	24	*Wacd* --
5	----------	15	*aad* 86	25	*aad* 102
6	*Eacd* 90	16	55	26	*Mac* 86
7	68	17	71	27	----------
8	----------	18	63	28	103
9	*Mc* 55	19	*Ec* 70	29	?*a* 72
10	*EEccdd* 134	20	*Mc* 74	30	? 50
				31	*a* --

Mean, 24 days=81.6.

a=Passage of an average-sized group through the central meridian.
b=Passage of a large group through the central meridian.
c=New formation of a group developing into a middle-sized or large center of activity: E, on the eastern part of the suns disk; W, on the western part; M, in the central circle zone.
d=Entrance of large or average-sized center of activity on the east limb.

AEROLOGICAL OBSERVATIONS

By EARL C. THOM

[Aerological Division, D. M. LITTLE in Charge]

There appear in this issue of the MONTHLY WEATHER REVIEW several important changes in and additions to the aerological data as presented heretofore. Data obtained by airplane flights and those obtained by radiosonde observations are presented as formerly in tables 1 and 1a, respectively.

The table presenting free-air resultant wind data (table 2) is expanded, data being published for 39 stations instead of 26 stations as previously. Moreover, these resultant wind data are based on observations made at 5 p. m. (E. S. T.) instead of 5 a. m. Data are shown in table 2 for any level if 10 observations or more were recorded at that level during the month; data as published in table 2 previously were based on 5 or more observations. Table 2 is further extended to upper levels showing data for the same levels as before and in addition data are shown for each higher even-thousand meter level at which 10 or more observations were recorded. As an aid in the interpretation of these data of table 2 the number of observations at each level for every station is shown as a small figure following the velocity.

Maximum wind velocities observed in the free air during pilot balloon flights are shown in table 3 as has previously been done.

Data setting forth the various heights of the tropopause during the month will appear as table 4. These data have not previously been shown.

In addition to the new and changed tabular material there appear in this summary five new charts. Charts VIII to XI show the resultant winds, the isobars and the isotherms at four upper levels, while chart XII presents an isentropic surface.

Table 4 and chart XII, and the discussion relating to them, have been prepared by the Air Mass Section of the Bureau.

In general, much more data appear in chart and tabular form than have previously been shown. These data are described and discussed below in detail.

The mean free-air pressures for the month as shown in tables 1 and 1a and charts VIII to XI, inclusive, indicate that the lowest pressures of the United States occur over the Northern Great Lakes; Sault Ste. Marie, Mich., having the lowest pressure observed within the United States for all levels above the surface up to 8,000 meters. At 10,000 meters and above, the low pressure area expands westward with equally low values recorded over Fargo and Sault Ste. Marie. Data are not available for stations in the extreme north and northeast except for Newfoundland. Based largely on these data and as shown by isobars drawn on charts VIII, IX, and X, there appears to be still lower pressures north of Newfoundland at levels from the surface up to at least 4,000 m. (m. s. l.). At all levels from the surface up to and including 5,000 m. pressure was highest at Pensacola, Fla.

The pressure gradient increases with altitude for levels from 500 to 5,000 meters. The difference in pressure between Pensacola and Sault Ste. Marie being 16, 24, and 29 mb. at the 1,000, 3,000, and 5,000 m. levels, respectively.

Mean free-air temperatures (°C.) (tables 1, 1a, and charts VIII to XI) above the surface are well distributed, and below 11,000 m. are in general colder with increasing latitude. At these levels the coldest upper-air layers were noted over northern Minnesota and the upper Great Lakes and to the northeastward while the warmest layers were over the Gulf Coast and the southern part of the United States. Mean free-air temperatures were below 0° C. over all the United States and Canada at and above 4,000 meters above sea level. As shown by table 1a, data for levels above 5,000 m. are available this month for 6 stations east of 100° W. longitude and north of 35° N. latitude and for Oakland, Calif., on the west coast. For levels between 11,000 m. and 18,000 m. the coldest layers of air are found over Nashville and the warmest over Sault Ste. Marie. The lowest mean free-air temperature shown is −72.2° C. (−98.0° F.) at 19,000 m. (62,336 ft. or 11.8 miles) above sea level over Nashville.

Mean relative humidies are highest in most air layers above the surface over northern Minnesota and the Northern Great Lakes. This area of relatively high humidity is roughly the same as corresponding areas of low pressures and low temperatures, especially at lower and intermediate levels. There is also an area of higher humidity over Utah and Nevada reaching from about the 1,000 m. level to the 4,000 m. level. The lowest relative humidities occur in general in connection with the regions of higher temperature near the Gulf and over Texas and southern New Mexico in the lower and intermediate levels. The lowest mean relative humidity for the month was 27 percent which was recorded at 5,000 m. above sea level over Pensacola. The relative humidity values shown in connection with temperatures below −40° C. are discarded as inaccurate, this accounts for the absence of humidity data for the higher levels in table 1a.

Resultant winds, indicating the mass transport of air in the free atmosphere, and based on pilot-balloon observations made near 5 p. m. (E. S. T.), are shown in table 2.

These resultant winds, when compared with the 5 a. m. (E. S. T.) normal resultants for this month show a distinct tendency toward a counterclockwise turning, from the normal over the eastern part of the country and the opposite tendency, a clockwise turning, over the western part of the country up to 1,500 meters. At 2,000 meters and above corresponding departures were not clearly separated. Departures were counterclockwise at all levels for five stations: Chicago, Omaha, Oklahoma City, Nashville and Atlanta. At only one station, Seattle, Wash., were departures clockwise at all levels.

The 5 p. m. resultant winds, as shown by table 2, are in general from westerly directions at all levels over the United States. Exceptions are noted at Las Vegas, Brownsville, Houston and Miami for the surface level, at Brownsville and Miami for the 500 m. level, and at Miami, Las Vegas, and San Diego for the 1,000 m. level. Resultant winds are westerly at all higher levels without exception.

With but very few exceptions the resultant velocity increased with elevation at all stations during the month. It is also noted that the resultant velocity was considerably above the 5 a. m. normal over most of the area. The resultant velocity was above normal at all levels, including surface, at eight widely scattered stations: Albuquerque, Cincinnati, Nashville, Oakland, Oklahoma City, St. Louis, Seattle, and Spokane. Resultant velocities were well below normal for all levels at Fargo, for all except lowest levels at Sault Ste. Marie, and for the intermediate levels at Omaha and Cheyenne. The maximum resultant velocity for the month, 27.3 meters per second (60.8 miles per hour) was recorded at the 6,000 m. level at Greensboro, N. C.

Table 3 shows the maximum free-air velocities which were recorded during the month in each of the three atmospheric layers, surface to 2,500 m., 2,500 m. to 5,000 m. and above 5,000 m. The maximum free-air velocity which was recorded during the month for the lowest of these three layers was 47.8 meters per second (106.9 miles per hour) reported on January 25 at 900 meters above sea level over Albany, N. Y. The corresponding maximum for the 2,500 to 5,000 m. layer was 63.4 meters per second (141.8 miles per hour) reported January 26 at 4,320 meters above sea level over Greensboro, N. C.; while the maximum for over 5,000 meters elevation was 95.5 meters per second (213.6 miles per hour) at 8,440 meters (5.2 miles) above sea level over Albuquerque on January 14.

This Albuquerque maximum establishes a new record for free-air velocities surpassing the previous record of 90 meters per second reported November 14, 1938, at Winslow, Ariz. The Albuquerque balloon flight of January 14 was observed with a single theodolite and was made with a large 100-gram balloon. Careful examination of the data of the particular flight as well as the evidence of balloon flights at other nearby stations that day indicate that the 95.5 meters per second velocity, while a very large value, can probably be accepted as correct. One reason for believing this a true velocity, and not a result of a slowly leaking balloon, is that above the 8,440 m. level the velocity decreased regularly at higher levels until at the maximum, 10,124 meters (6.3 miles), the velocity was only 25 m. per second (55.9 miles per hour).

In connection with the maximum velocities for the month, it is interesting to note that the mean of the maximum velocities for the lowest layer over the nine sections of the country is 41.4 meters per second (92.6 mi./hr.), the corresponding mean for the 2,500 to 5,000 m. layer is 52.3 meters per second (117 mi./hr.) and the mean for above 5,000 meters is 65.5 meters per second (146.5 miles per hour). Above 5,000 m. one maximum wind was reported from a direction south of west, one from the west, the seven others were all from direction to the north of west.

Chart VIII shows the 5 a. m. (E. S. T.) resultant winds for the 1,500 m. level. Isotherms are also drawn for this level. To permit the use of the 5,000 ft. pressures available for a large number of western stations, isobars are drawn on this chart for the 1,524 meter (5,000 ft.) level.

Chart IX shows data for the 3,000 m. level corresponding to that given on chart VIII.

Charts X and XI show corresponding data for the 4,000 and 5,000 m. levels, respectively, except that the resultant wind data is based on observations made at 5 p. m. (E. S. T.).

The decision to use the 5 p. m. observations for resultant wind data for the two upper levels, as shown on charts X and XI, was prompted by the fact that in the Bureau, records for most stations show that a considerably greater number of observations reach these levels at that time of day than at 5 a. m. Furthermore, it is believed that the diurnal variation of winds, at these levels, is on the average, sufficiently small to justify the use of the greater number of observations although made some 12 hours later than the temperature and pressure observations with which they are charted.

Data shown on charts VIII to XI for stations within the United States and Canada are based on observations at 5 a. m. and 5 p. m. (E. S. T.) as shown above. The resultant winds shown on these charts for St. Julian, Cuba, are based on 7:30 a. m. (E. S. T.) and those for Antilla, Cuba, on 6:30 a. m. (E. S. T.). Corresponding data for Mazatlan, Mexico, are based on observations at 11 a. m. (E. S. T.); those for Hermosillo, Mexico, on 9 a. m. (E. S. T.); the 1,500 and 3,000 m. resultants for Tampico, Mexico, are based on 8 a. m. (E. S. T.) observations and those for the two higher levels for the same city on 2 p. m. (E. S. T.) observations. The resultant winds shown on these charts for Bermuda are based on pilot-balloon observations taken between the hours of 6:30 and 9:30 a. m. (E. S. T.).

TROPOPAUSE DATA

Table 4 is a summary of tropopause heights and temperatures for January 1939 prepared by the Air Mass Section of the Weather Bureau, and based on radiosonde observations. In summarizing these data, instead of designating a single tropopause for each sounding determined by the existence of a discontinuous change of temperature lapse rate equal to or greater than some arbitrarily prescribed value, the idea of a "multiple tropopause" as suggested by J. Bjerknes and Palmén [1] has been followed. These authors found that if an arbitrary rule is followed in which the tropopause is defined as the level where the temperature gradient definitely sinks below a certain limit, for instance 2° C. per 1,000 dynamic meters, the tropopause would change in certain cases from hour to hour at a given station due to a point as much as 1,000 meters higher or lower changing its temperature by 1° or 2°. When a network of stations is considered, the difficulty becomes even greater. A tropopause found at one station would, according to the usual method of identification of significant points in a station network by potential temperature, correspond at another station to some temperature inversion rather low in the troposphere or perhaps some minor discontinuity high in the stratosphere. Bjerknes and Palmén showed that in some individual soundings a single, well-defined tropopause is evident, but in many cases several significant points can be designated as tropopauses. At a given time each of several significant tropopause points at one station usually is associated with corresponding significant points at other stations, but the particular point most likely to be designated as the tropopause from the usual arbitrary rules at one station may not correspond with the significant point similarly selected for the tropopause at any other place. Consequently, it is advisable to consider each significant point, at least within certain limits, as representing a possible tropopause. Bjerknes and Palmén suggested that these "multiple tropopauses" be classified according to potential temperature, as that is the principle element used in identifying significant points.

In table 4 the multiple tropopauses are classified according to 10-degree ranges of potential temperature from 290° A to 399° A. All significant points in this interval of potential temperature showing a decrease of lapse rate were tabulated from the daily ascents at each station. Points at which the temperatures were higher than −25° C. were not considered. The mean altitude and mean temperature of points occurring in each 10° interval of potential temperature have been entered in the second and third columns for each station in the table and the number of cases in the first column. The weighted mean altitude and temperature for all cases over the entire 110° interval appears at the bottom, and finally the weighted mean potential temperature for all cases at each station is given. In spite of the rather arbitrary limits (temperatures lower than −25° C. and potential temperatures

[1] Bjerknes, J., and Palmén, E.: Investigations of selected European cyclones by means of serial ascents, Norske Videnskaps-Akademi, Geofysiske Publikasjoner, Vol. 12, No. 2, 1937.

from 290° to 399°) the summarized result gives reasonable values.

Apparently this is the first time that mean tropopause data have been summarized in this form. It is possible that with more experience in this procedure it will be necessary to make minor changes.

MEAN ISENTROPIC CHART

Chart XII represents a mean isentropic chart for the month of January 1939, using a potential temperature of 295° A.

The chart has been constructed in accordance with methods used in the Air Mass Section of the Weather Bureau, and described in a circular letter of September 29, 1938. The data used are the mean free-air data from APOB, RAOB, and pilot-balloon stations published elsewhere in this issue of the REVIEW. It was necessary to use a few resultant winds from the 5 p. m. observations, and these are designated by the letters (P. M.) printed near them. At stations where the height of the isentropic surface is only roughly estimated, because of insufficient data, the winds are plotted at the altitude indicated.

It is realized that air flow is not even approximately isentropic over a period of a whole month, but presumably a mean isentropic chart will give a better indication of the sources and mean trajectories of moist and dry air than would a constant level chart.

A study of mean isentropic charts indicates that precipitation areas are correlated with the position of moist and dry tongues. In the winter months the greatest areas of positive departure in precipitation are found to lie to the north of the moist tongues, where the upflow is most pronounced, whereas in the summer time they lie farther within the moist areas.

TABLE 1.—*Mean free-air barometric pressures (P) in mb, temperatures (T) in °C, and relative humidities (R H) in percent obtained by airplanes during January 1939*

Stations and elevations in meters above sea level	Altitude (meters) m. s. l.																													
	Surface				500			1,000			1,500			2,000			2,500			3,000			4,000			5,000					
	Number of observations	P.	T.	R. H.	P.	T.	R. H.	P.	T.	R. H.	P.	T.	R. H.	P.	T.	R. H.	P.	T.	R. H.	P.	T.	R. H.	P.	T.	R. H.	P.	T.	R. H.			
Billings, Mont. (1,090 m.)	30	888	−0.1	59							844	1.4	52	793	−1.8	51	744	−5.2	53	698	−8.4	55	613	−14.6	59	536	−21.0	60			
Cheyenne, Wyo. (1,873 m.)	31	807	−3.7	64										794	−1.2	55	746	−3.1	52	700	−6.3	52	615	−12.9	52	539	−19.6	48			
Chicago, Ill. (187 m.)	29	993	−1.7	83	954	−1.9	81	896	−2.7	78	841	−3.6	70	790	−5.7	69	741	−7.9	68	694	−10.3	64	609	−15.5	58	533	−21.3	56			
Coco Solo, C. Z.[1] (15 m.)	31	1,011	25.3	84	956	22.3	88	903	19.3	84	852	16.4	79	802	14.2	70	756	13.2	48	712	11.4	35	631	5.6	35	558	0.4	22			
El Paso, Tex. (1,193 m.)	31	883	2.7	55							851	6.6	45	800	4.4	41	752	1.8	40	706	−1.0	39	622	−6.8	38	546	−14.0	38			
Lakehurst, N. J.[1] (39 m.)	22	1,015	−0.6	77	957	−0.5	70	900	−1.8	69	845	−2.6	61	792	−4.1	55	743	−6.8	52	697	−9.1	52	611	−15.3	53						
Norfolk, Va.[1] (10 m.)	19	1,020	4.2	87	960	5.4	80	904	3.2	70	849	2.3	61	798	0.3	58	750	−2.1	54	703	−4.5	48	619	−9.8	41	543	−16.5	38			
Pearl Harbor, T. H.[1] (6 m.)	31	1,016	20.9	80	960	20.1	73	906	17.0	80	854	15.4	70	805	14.2	52	758	12.3	43	714	9.9	38	632	5.4	32	559	0.0	34			
Pensacola, Fla.[1] (13 m.)	25	1,021	9.8	87	964	11.0	66	908	9.1	62	854	7.8	54	804	6.3	51	755	4.5	42	710	2.6	33	626	−3.3	28	552	−9.5	27			
St. Thomas, V. I.[1] (8 m.)	15	1,018	23.9	77	963	21.1	87	908	18.1	84	857	14.8	83	808	12.2	74	761	10.8	57	716	8.6	45	634	4.6	30						
Salt Lake City, Utah (1,288 m.)	31	873	−1.7	85							850	−0.5	75	799	−2.2	71	750	−4.4	71	704	−7.3	70	618	−12.9	64	541	−18.9	56			
San Diego, Calif.[1] (10 m.)	29	1,017	8.3	84	960	10.4	77	904	9.0	68	851	6.8	61	800	4.7	55	752	2.1	52	706	−0.6	49	623	−6.8	47	547	−13.3	46			
Seattle, Wash.[1] (10 m.)	20	1,017	6.1	83	958	4.0	79	901	0.7	79	846	−1.6	77	795	−4.5	75	745	−7.3	68	699	−10.4	67	612	−17.6	74						
Spokane, Wash. (597 m.)	30	947	0.7	87				901	−0.2	82	846	−1.4	71	794	−4.1	70	745	−7.1	74	698	−10.1	75	613	−15.5	70	536	−21.8	67			

Observations taken about 4 a. m. 75th meridian time, except by Navy stations along the Pacific coast and Hawaii where they are taken at dawn.

[1] Navy.

NOTE.—None of the means included in this table are based on less than 15 surface or 5-standard-level observations.

TABLE 1a.—*Mean free-air barometric pressures (P) in mb, temperatures (T) in °C. and relative humidities (R H) in percent obtained by radiosonde during January 1939*

Altitude (meters) m. s. l.	Stations and elevations in meters above sea level																													
	Fargo, N. Dak. (274 m.)				Nashville, Tenn. (180 m.)				Oakland, Calif. (2 m.)				Oklahoma City, Okla. (391 m.)				Omaha, Nebr. (300 m.)				Sault Ste. Marie, Mich. (221 m.)				Washington, D. C.[1] (13 m.)							
	Number of Observations	P.	T.	R. H.	Number of Observations	P.	T.	R. H.	Number of Observations	P.	T.	R. H.	Number of Observations	P.	T.	R. H.	Number of Observations	P.	T.	R. H.	Number of Observations	P.	T.	R. H.	Number of Observations	P.	T.	R. H.			
Surface	31	981	−12.9	92	31	997	4.3	80	31	1,020	6.5	88	30	971	3.5	77	31	979	−1.9	78	31	986	−10.5	89	29	1,017	0.5	81			
500	31	953	−10.6	91	31	958	4.7	76	31	960	7.9	77	30	957	4.8	73	31	955	−0.5	73	31	952	−10.1	90	29	958	0.8	66			
1,000	31	893	−7.4	85	31	901	3.3	73	31	904	7.1	68	30	901	5.4	60	31	897	0.2	67	31	892	−10.3	89	29	901	−0.5	63			
1,500	31	837	−6.9	80	31	847	1.8	65	31	850	5.4	62	30	847	3.7	55	31	843	−0.9	61	31	835	−11.1	85	29	846	−1.8	63			
2,000	31	785	−8.6	77	31	796	−0.2	60	31	799	3.4	55	30	796	1.4	49	31	791	−3.4	58	31	783	−12.8	81	29	795	−2.6	63			
2,500	30	736	−11.0	74	31	748	−1.9	54	31	751	0.6	51	30	748	−1.1	47	31	742	−6.3	56	31	733	−14.6	78	29	746	−5.1	62			
3,000	30	689	−13.8	72	30	702	−3.7	48	31	706	−2.1	50	30	702	−3.5	47	31	696	−9.1	55	31	686	−16.2	75	29	699	−7.2	60			
4,000	30	603	−19.6	70	30	618	−8.7	41	31	622	−8.3	50	30	618	−9.1	44	31	611	−14.9	55	31	600	−21.1	73	29	614	−12.0	54			
5,000	30	526	−25.5	66	30	542	−14.6	39	31	546	−14.8	50	30	542	−15.6	43	31	534	−21.6	55	30	523	−27.3	71	29	538	−18.1	51			
6,000	29	458	−33.0	64	30	474	−21.1	40	31	477	−21.2	49	30	474	−22.0	41	31	466	−28.4	53	30	454	−33.8	69	29	470	−24.5	51			
7,000	29	396	−40.5	63	29	414	−27.6	41	31	416	−28.1	48	30	413	−29.5	41	31	404	−35.9	52	30	393	−40.2	68	27	409	−31.1	50			
8,000	28	341	−47.4	----	28	359	−33.9	41	31	361	−35.2	48	30	359	−36.5	40	30	349	−43.0	----	29	339	−46.1	----	26	355	−38.1	----			
9,000	27	292	−52.2	----	28	310	−40.9	40	31	312	−42.5	48	27	309	−43.6	----	30	300	−48.8	----	29	291	−50.0	----	24	306	−44.0	----			
10,000	27	250	−54.9	----	28	267	−48.0	----	29	269	−49.7	----	25	266	−50.1	----	30	258	−52.7	----	28	250	−51.3	----	22	263	−48.9	----			
11,000	27	214	−55.0	----	27	229	−54.0	----	26	230	−55.2	----	23	228	−55.0	----	29	221	−55.6	----	25	214	−51.0	----	18	226	−52.8	----			
12,000	27	183	−55.2	----	27	196	−58.8	----	25	196	−57.9	----	23	194	−58.2	----	27	188	−57.3	----	23	183	−52.2	----	15	194	−54.9	----			
13,000	25	156	−56.2	----	26	166	−61.4	----	23	167	−57.9	----	22	166	−59.4	----	26	160	−58.4	----	20	157	−53.1	----	14	166	−55.5	----			
14,000	21	134	−56.9	----	26	141	−63.4	----	22	142	−58.8	----	21	141	−60.8	----	23	137	−59.5	----	16	134	−53.6	----	10	142	−57.4	----			
15,000	16	114	−58.7	----	23	120	−66.1	----	18	121	−60.3	----	17	120	−63.4	----	21	117	−61.2	----	10	115	−55.5	----	9	121	−59.6	----			
16,000	12	97	−60.5	----	21	101	−69.0	----	16	103	−61.5	----	12	102	−65.9	----	19	99	−64.0	----	9	97	−57.4	----	8	104	−61.8	----			
17,000	8	83	−61.1	----	17	85	−71.4	----	10	88	−62.8	----	7	86	−67.0	----	17	84	−65.2	----	------	------	------	----	6	89	−63.2	----			
18,000	------	------	------	----	10	72	−71.4	----	6	74	−62.9	----	------	------	------	----	9	72	−66.0	----	------	------	------	----	------	------	------	----			
19,000	------	------	------	----	6	60	−72.2	----	------	------	------	----	------	------	------	----	6	61	−68.0	----	------	------	------	----	------	------	------	----			

Observations taken about 4 a. m., 75th meridian time, except by Navy stations along the Pacific coast and Hawaii where they are taken at dawn.

[1] Navy.

NOTE.—None of the means included in this table are based on less than 15 surface or 5 standard-level observations.

Number of observations refers to pressure only as temperature and humidity data are missing for some observations at certain levels also the humidity data is not used in daily observations when the temperature is below −40° C.

TABLE 2.—*Free-air resultant winds based on pilot-balloon observations made near 5 p. m. (E. S. T.) during January 1939*

[Directions given in degrees from North (N=360°, E=90°, S=180°, W=270°)—Velocities in meters per second (Superior Figures Indicate Number of Observations]

Altitude (meters) m. s. l.	Abilene, Tex. (537 m.)		Albuquerque, N. Mex. (1,554 m.)		Atlanta, Ga. (302 m.)		Billings, Mont. (1,095 m.)		Boise, Idaho (850 m.)		Brooklyn, N. Y. (15 m.)		Brownsville, Tex. (7 m.)		Buffalo, N. Y. (220 m.)		Burlington, Vt. (132 m.)		Charleston, S. C. (18 m.)		Cheyenne, Wyo. (1,873 m.)		Chicago, Ill. (192 m.)		Cincinnati, Ohio (157 m.)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°		°		°		°		°		°		°		°	
Surface	239	3.4[20]	311	1.7[31]	270	3.0[27]	282	4.7[21]	319	0.4[27]	288	3.7[29]	130	3.0[26]	254	3.2[28]	216	1.8[37]	232	1.6[20]	274	5.2[29]	252	2.0[31]	233	2.5[31]
500					277	4.2[27]					285	6.3[27]	145	4.5[28]	247	5.5[28]	234	4.0[37]	237	4.0[36]			255	4.7[29]	230	5.7[29]
1,000	230	4.8[30]			263	5.5[27]			319	0.5[27]	287	10.7[21]	306	0.4[21]	245	10.5[16]	267	6.9[33]	257	7.2[26]			252	8.7[13]	237	9.9[33]
1,500	252	6.1[30]			266	7.5[34]	271	8.5[33]	286	0.7[27]	288	14.0[21]	266	3.9[18]	256	11.9[13]	288	9.5[30]	268	10.9[33]			270	12.7[13]	245	13.3[19]
2,000	256	9.6[28]	288	2.8[30]	274	10.2[22]	280	8.8[26]	281	3.4[28]	289	16.1[19]	241	8.7[17]			298	12.4[12]	272	11.5[23]	281	6.6[29]	273	15.8[10]	266	15.5[18]
2,500	258	11.2[28]	283	6.6[29]	274	12.8[21]	289	9.7[30]	288	7.0[34]	295	18.2[16]	254	8.5[13]			295	13.4[11]	270	13.6[30]	287	9.4[29]			274	15.5[14]
3,000	254	13.0[25]	298	8.7[25]	275	13.2[15]	289	10.5[27]	292	8.3[31]	291	20.6[13]	264	10.1[11]					275	15.5[30]	291	10.9[29]				
4,000	254	15.6[26]	296	12.9[23]	273	16.0[13]	298	16.4[19]	304	10.2[14]									271	16.5[19]	294	12.5[27]				
5,000	265	19.2[18]	302	15.9[20]			298	21.6[14]													295	14.0[18]				
6,000	256	19.7[12]	314	20.1[14]			299	21.3[13]													302	18.3[13]				
8,000			317	20.4[13]																						
10,000			309	21.3[12]																						

Altitude (meters) m. s. l.	El Paso, Tex. (1,196 m.)		Fargo, N. Dak. (283 m.)		Greensboro, N. C. (271 m.)		Havre, Mont. (766 m.)		Houston, Tex. (21 m.)		Huron, S. Dak. (393 m.)		Las Vegas, Nev. (570 m.)		Little Rock, Ark. (m.)		Medford, Oreg. (410 m.)		Miami, Fla. (10 m.)		Minneapolis, Minn. (261 m.)		Nashville, Tenn. (194 m.)		New Orleans, La. (19 m.)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°		°		°		°		°		°		°		°	
Surface	259	2.7[31]	314	1.5[31]	265	2.1[28]	259	3.8[25]	156	0.9[28]	314	1.5[29]	34	0.6[29]			210	0.5[31]	104	2.6[31]	257	0.5[33]	230	2.5[27]	200	0.6[31]
500			224	1.4[32]	256	4.2[25]			196	1.9[28]	304	2.2[29]					215	0.6[17]	131	2.9[31]	264	1.4[21]	223	4.3[27]	205	2.2[31]
1,000			263	3.3[31]	256	6.9[26]	267	8.1[28]	244	2.4[32]	295	5.8[25]	45	0.8[30]			221	2.4[17]	172	1.5[30]	266	3.8[33]	236	6.3[28]	234	3.7[29]
1,500	262	3.7[31]	288	6.0[19]	266	9.4[25]	282	11.8[25]	263	6.1[31]	298	9.1[34]	340	1.2[30]			213	4.3[17]	245	2.7[27]	278	7.0[30]	254	9.4[32]	259	5.2[29]
2,000	266	5.6[31]	301	8.2[16]	275	12.0[27]	288	12.3[28]	268	10.6[19]	296	9.8[32]	306	2.1[28]			243	5.6[17]	255	3.8[30]	279	8.9[17]	260	12.3[22]	266	7.3[19]
2,500	282	7.8[30]	293	9.8[14]	277	14.4[28]	292	13.5[25]	275	12.8[16]	291	11.0[31]	330	3.9[25]			259	6.2[12]	264	5.1[31]	285	11.0[14]	264	14.7[21]	278	6.9[17]
3,000	286	9.5[26]	290	11.5[12]	273	18.2[26]	292	13.1[21]	277	11.8[13]	289	13.1[21]	324	5.2[25]			280	8.6[11]	274	6.7[10]	282	11.4[13]	272	15.7[15]	273	9.0[16]
4,000	275	11.5[25]	292	15.2[13]	278	22.9[33]	299	16.5[12]	270	12.9[16]	291	14.8[19]	314	7.2[21]					265	8.9[13]			268	16.4[19]	265	14.6[14]
5,000	278	16.0[22]			279	24.1[14]					289	17.7[16]	314	10.4[23]					262	9.9[12]					257	15.8[19]
6,000	275	17.9[15]			275	27.3[16]					295	20.8[17]	312	12.3[22]												
8,000											294	23.1[13]	341	14.9[18]												
10,000											279	24.1[11]	335	22.0[15]												
12,000													313	16.2[12]												
14,000													293	15.4[10]												

Altitude (meters) m. s. l.	Oakland, Calif. (8 m.)		Oklahoma City, Okla. (402 m.)		Omaha, Nebr. (306 m.)		Reno, Nev. (1,346 m.)		St. Louis, Mo. (170 m.)		Salt Lake City, Utah (1,294 m.)		San Diego, Calif. (15 m.)		San Juan, P. R. (16 m.)		Sault Ste. Marie, Mich. (198 m.)		Seattle, Wash. (14 m.)		Spokane, Wash., (603 m.)		Washington D. C. (10 m.)		Winslow, Ariz. (1,488 m.)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°		°		°		°		°		°		°		°	
Surface	279	1.3[27]	235	2.3[31]	302	1.7[29]	241	1.7[31]	235	1.9[28]	236	1.2[30]	268	2.4[29]	80	6.6[31]	257	0.8[21]	205	3.4[27]	210	1.8[31]	291	2.1[29]	282	2.9[21]
500	350	2.0[27]	227	3.3[29]	283	2.1[29]			236	5.6[30]			300	1.4[29]	90	8.4[31]	279	2.0[21]	201	6.4[27]			265	5.3[28]		
1,000	359	4.2[28]	241	5.1[25]	276	4.1[27]			256	8.6[31]			45	1.1[28]	95	7.8[31]	279	3.8[20]	209	8.6[19]	212	3.8[25]	263	8.7[16]		
1,500	343	5.1[24]	256	7.6[29]	282	6.8[26]	235	1.7[31]	276	12.3[22]	204	1.8[30]	16	2.4[31]	96	6.6[31]	315	5.1[16]	225	7.4[10]	218	6.7[16]	284	12.6[18]		
2,000	341	6.5[22]	257	8.9[27]	285	9.3[21]	249	2.3[31]	284	14.3[21]	213	1.7[29]	4	4.4[22]	100	5.9[25]	307	5.0[14]	232	9.2[12]	233	7.7[14]	289	17.8[23]	274	3.0[28]
2,500	322	7.0[20]	256	11.3[26]	288	11.5[19]	266	3.5[26]	286	14.8[20]	271	2.8[29]	355	4.2[15]	87	6.1[21]	305	6.6[13]			239	8.0[13]	285	19.8[21]	284	4.7[29]
3,000	326	10.1[19]	261	13.2[26]	286	13.7[16]	283	5.6[27]	283	14.5[18]	285	5.5[31]	336	5.4[17]	83	4.7[19]	309	9.0[12]			253	10.4[11]	282	19.4[19]	280	5.3[29]
4,000	334	10.7[13]	265	17.6[24]	285	19.4[13]	305	9.7[22]			286	7.9[19]	323	6.6[14]	89	3.5[12]							271	22.1[13]	297	7.8[21]
5,000	343	13.8[11]	274	19.7[19]	288	21.7[15]	321	13.8[19]			287	10.3[13]	311	9.2[10]											306	11.2[20]
6,000			278	23.9[13]	289	22.4[14]	322	15.4[17]																	311	14.7[23]
8,000																									315	17.5[19]
10,000																									311	17.3[13]
12,000																									302	17.7[10]
14,000																									284	18.6[10]

TABLE 3.—*Maximum free-air wind velocities (M. P. S.), for different sections of the United States based on pilot balloon observations during January 1939*

Section	Surface to 2,500 meters (m. s. l.)					Between 2,500 and 5,000 meters (m. s. l.)					Above 5,000 meters (m. s. l.)				
	Maximum velocity	Direction	Altitude (m.) M. S. L.	Date	Station	Maximum velocity	Direction	Altitude (m.) M. S. L.	Date	Station	Maximum velocity	Direction	Altitude (m.) M. S. L.	Date	Station
Northeast [1]	47.8	WNW	900	25	Albany, N. Y.	51.2	NW	3,720	25	Pittsburgh, Pa.	53.5	WNW	5,580	12	Albany, N. Y.
East-Central [2]	43.4	NW	1,180	31	Washington, D. C.	63.4	W	4,320	26	Greensboro, N. C.	64.0	W	11,800	8	Nashville, Tenn.
Southeast [3]	42.0	SW	2,440	30	Jacksonville, Fla.	47.6	WSW	3,520	18	Jacksonville, Fla.	41.0	WNW	11,450	8	Charleston, S. C.
North-Central [4]	39.0	WNW	2,400	1	Bismark, N. Dak.	49.6	NNW	4,990	27	Fargo, N. Dak.	72.5	NW	10,920	26	Huron, S. Dak.
Central [5]	50.2	SW	2,320	9	Wichita, Kans.	50.0	NW	4,960	26	Omaha, Nebr.	58.0	WNW	9,560	19	Wichita, Kans.
South-Central [6]	37.7	SW	1,530	31	Amarillo, Tex.	45.7	W	5,000	17	Abilene, Tex.	55.2	WNW	9,040	30	Del Rio, Tex.
Northwest [7]	40.2	W	1,940	2	Havre, Mont.	53.5	SW	4,500	1	Medford, Oreg.	72.0	NNW	6,580	14	Billings, Mont.
West-Central [8]	29.4	W	2,290	19	Cheyenne, Wyo.	54.0	WNW	3,480	25	Rock Springs, Wyo.	77.5	WSW	9,350	3	Redding, Calif.
Southwest [9]	43.0	W	2,370	28	El Paso, Tex.	56.0	NNW	5,000	18	Albuquerque, N. Mex.	95.5	NNW	8,440	14	Albuquerque, N. Mex.

[1] Maine, Vermont, New Hampshire, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania, and northern Ohio.
[2] Delaware, Maryland, Virginia, West Virginia, southern Ohio, Kentucky, eastern Tennessee, and North Carolina.
[3] South Carolina, Georgia, Florida, and Alabama.
[4] Michigan, Wisconsin, Minnesota, North Dakota, and South Dakota.
[5] Indiana, Illinois, Iowa, Nebraska, Kansas, and Missouri.
[6] Mississippi, Arkansas, Louisiana, Oklahoma, Texas (except El Paso), and western Tennessee.
[7] Montana, Idaho, Washington, and Oregon.
[8] Wyoming, Colorado, Utah, northern Nevada, and northern California.
[9] Southern California, southern Nevada, Arizona, New Mexico, and extreme west Texas.

TABLE 4.—*Mean altitudes and temperatures of significant points identifiable as tropopauses during January 1939, classified according to the potential temperatures (10-degree intervals between 290 and 399° A.) with which they are identified. (Based on radiosonde observations.) All actual temperatures are in degrees centigrade below zero*

Potential temperatures °A.	Fargo, N. Dak.			Nashville, Tenn.			Oakland, Calif.			Oklahoma City, Okla.			Omaha, Nebr.			Sault Ste. Marie, Mich.			Washington, D. C.		
	Number of cases	Mean altitude	Mean temperature	Number of cases	Mean altitude	Mean temperature	Number of cases	Mean altitude	Mean temperature	Number of cases	Mean altitude	Mean temperature	Number of cases	Mean altitude	Mean temperature	Number of cases	Mean altitude	Mean temperature	Number of cases	Mean altitude	Mean temperature
290–299	1	6.5	50.0	------	------	------	1	6.6	41.0	------	------	------	4	7.3	48.2	12	7.0	47.3	------	------	------
300–309	17	8.4	53.2	2	7.3	39.5	2	7.0	36.5	------	------	------	10	7.9	48.6	19	7.9	48.9	5	7.4	42.6
310–319	14	9.5	57.2	4	7.8	38.2	4	8.8	47.0	10	8.8	47.4	19	9.4	54.8	17	9.1	54.6	7	8.8	46.8
320–329	9	9.9	54.4	15	9.5	47.2	16	10.7	56.4	16	10.3	53.8	16	10.4	55.9	10	9.9	53.7	10	10.0	53.5
330–339	3	10.3	53.3	18	11.7	61.3	12	11.3	57.1	13	11.4	58.3	8	11.4	60.3	4	11.4	60.5	6	11.2	57.5
340–349	------	------	------	10	11.8	57.9	9	12.3	60.1	6	12.5	62.1	4	12.2	58.0	4	11.0	54.7	3	12.2	60.3
350–359	2	12.0	58.0	4	13.7	67.0	4	12.3	55.0	3	11.1	51.3	2	12.2	53.0	3	12.0	56.7	------	------	------
360–369	2	12.2	55.0	7	14.2	67.0	1	15.1	73.0	------	------	------	3	13.0	55.7	4	12.4	53.5	------	------	------
370–379	------	------	------	3	15.0	67.7	7	14.0	59.0	4	15.0	71.2	6	14.2	61.3	5	12.7	52.2	------	------	------
380–389	------	------	------	3	15.9	73.3	2	14.4	59.0	------	------	------	2	14.9	65.5	1	13.1	51.0	------	------	------
390–399	------	------	------	2	16.8	75.0	2	15.9	63.3	1	14.5	57.0	4	14.8	57.0	1	13.5	50.0	2	15.6	64.0
All (weighted mean)	------	9.4	54.8	------	11.7	57.8	------	11.6	56.5	------	11.0	55.9	------	10.6	55.7	------	9.4	52.1	------	10.1	52.4
Weighted mean potential temperature, °A.	317.4			341.7			339.1			334.1			331.3			322.5			327.2	

RIVERS AND FLOODS

[River and Flood Division, MERRILL BERNARD in charge]

By THOMAS S. SOUTHWICK

Precipitation during January was above normal over most of the country, but durations and intensities were not sufficient to cause other than minor flooding. This condition was changed abruptly on the 30th by widespread precipitation which inaugurated a flood situation that extended into February.

The west fork of the White River in Indiana went slightly above flood stage on the 7th and the Rock River in Illinois on the 10th. High temperatures—the week ending January 10 being one of the warmest January weeks of record—contributed an increment of melted snow to the rains causing these overflows.

Heavy rains over the Southeastern States on January 12–13 caused flood stages to be exceeded on the Tombigbee and Pearl Rivers. The Pearl River at Jackson, Miss., was above flood stage from January 17 to 25. Damage estimated at $1,000 occurred at Pearl River, La., due to the suspension of lumbering operations.

A slight, flashy rise occurred on the Sulphur River at Ringo Crossing, Tex., due to local rains on January 23–24.

Table of flood stages during January 1939

River and station	Flood stage	Above flood stages—dates		Crest	
		From—	To—	Stage	Date
ATLANTIC SLOPE DRAINAGE					
French Broad: Asheville, N. C.	Feet 6	30	30	6.6	Feet 30
EAST GULF OF MEXICO DRAINAGE					
Tombigbee: Lock No. 3, Ala.	33	15	20	38.4	18
Pearl:					
Jackson, Miss.	18	17	25	20.5	21
Pearl River, La.	12	20	22	12.2	21
MISSISSIPPI SYSTEM					
Upper Mississippi Basin					
Rock: Moline, Ill.	10	10	10	10.3	10
Tygart:	Feet				Feet
Dailey, W. Va.	11	30	(1)	13.4	31
Elkins, W. Va.	14	31	(1)	14.8	31
Belington, W. Va.	14	31	(1)	15.6	31
Midvale, W. Va.	11	30	31	12.3	30
Philippi, W. Va.	20	31	31	20.0	31
Monongahela: Lock No. 7, Greensboro, Pa.	30	31	(1)	31.6	31
Walhonding: Walhonding, Ohio	8	31	(1)	------	------
Little Sandy: Grayson, Ky.	15	30	(1)	------	------
Kentucky: Lock No. 9, Ky.	20	30	(1)	21.3	30
Barren: Bowling Green, Ky.	20	30	(1)	------	------
Green:					
Munfordville, Ky.	28	30	(1)	------	------
Lock No. 6, Brownsville, Ky.	28	30	(1)	------	------
Lock No. 4, Woodbury, Ky.	33	30	(1)	------	------
West Fork of White:					
Anderson, Ind.	10	31	(1)	------	------
Elliston, Ind.	18	30	(1)	------	------
Edwardsport, Ind.	12	7	8	13.0	8
White Basin					
Black: Black Rock, Ark.	14	30	(1)	16.9	31
Lower Mississippi Basin					
St. Francis: Fisk, Mo.	20	31	(1)	------	------
Red Basin					
Sulphur: Ringo Crossing, Tex.	20	24	24	21.0	24

Table of flood stages during January 1939—Continued

[1] Continued into next month.

The month closed with stages rising throughout the Ohio Valley and the Atlantic coast region when a disturbance, which was centered over Texas the morning of the 28th, traversed the Ohio Valley attended by widespread and heavy rainfall. Except for a few headwater stations where crests were attained on the 30th and 31st, the rises continued and culminated in the floods of February. Discussion of the rises of January 30 and 31 will be included in the report for February.

WEATHER ON THE ATLANTIC AND PACIFIC OCEANS

[The Marine Division, WILLIS E. HURD acting in charge]

NORTH ATLANTIC OCEAN, JANUARY 1939

By H. C. HUNTER

Atmospheric pressure.—Most of the North Atlantic had pressure averaging below normal. The greatest deficiency was found over waters near Ireland and thence southwestward toward the Azores. In contrast, the north-central and northeastern areas had pressure averaging above the normal, the mean at Reykjavik, Iceland, being 0.34 inch higher.

The month was remarkable for fluctuations of large amount in the pressure readings, often occurring very rapidly. The lowest marks at Horta and Lisbon, 29.30 and 29.09 inches, respectively, are notably low for those localities. At Halifax, from the 22d to 25th, inclusive, the 8:30 a. m. readings were as follows: 30.00, 29.00, 30.12, and 29.12 inches. Pressure at Reykjavik was mainly below normal from the 14th to the 22d, but almost constantly much above normal during the remainder of the month. In the early portion of the month the center of the Icelandic LOW was shifted to southeastward or southward of its ordinary location, but during the final fortnight usually to westward.

The extremes of the month, given in reports that vessels have sent to this office, are 30.60 and 28.02 inches. The high mark was noted during the forenoon of the 28th, about 100 miles to northeastward of Cape Henry, by the American tank steamer *John D. Archbold*. There was remarkably low pressure to westward of Ireland on the 14th and 15th, and the reading 28.02 appears in the late evening radio report of the 15th from an unidentified vessel near 55° N., 15° W. The report by mail of the American liner *Black Hawk*, 2 p. m. of the 14th, near 50° N., 20° W., shows 28.15 inches. A press clipping indicates that the German liner *New York*, from Cobh toward New York, when off the Irish coast on the 15th, noted pressure of 27.7 inches.

Cyclones and gales.—The month was unusually stormy; vessel reports so far received include 18 instances of force-12 winds and 20 of force 11. The accompanying table of ocean gales and storms does not include all of the force-11 encounters. There were periods of much less storminess over the most traversed parts of the ocean, particularly the 9th to 13th, and the 27th to 29th. The 14th to 22d was the most turbulent period.

TABLE 1. *Averages, departures, and extremes of atmospheric pressure (sea level) at selected stations for the North Atlantic Ocean and its shores, January 1939.*

Station	Average pressure	Departure	Highest	Date	Lowest	Date
	Inches	*Inch*	*Inches*		*Inches*	
Julianehaab, Greenland	29.60	+0.17	30.14	5	29.24	29
Reykjavik, Iceland	29.80	+.34	30.42	25	28.38	20
Lerwick, Shetland Islands	29.56	−.14	30.39	30	28.50	16
Valencia, Ireland	29.58	−.32	30.27	23	28.56	16
Lisbon, Portugal	[1] 30.07	−.08	30.45	23	29.09	28
Madeira	30.11	+.01	30.42	22	29.65	27
Horta, Azores	29.96	−.20	30.42	3	29.30	31
Belle Isle, Newfoundland	29.61	−.13	30.44	6	28.64	12
Halifax, Nova Scotia	29.86	−.12	30.58	6	29.00	23
Nantucket	29.96	−.08	30.53	8	29.24	22
Hatteras	30.08	−.06	30.53	28	29.45	18
Bermuda	30.10	−.06	30.48	29	29.72	19
Turks Island	30.08	+.03	30.14	1	29.97	18
Key West	30.09	−.01	30.30	21	29.89	14
New Orleans	30.12	−.01	30.56	25	29.52	29

[1] For 23 days.

NOTE.—All data based on a. m. observations only, with departures compiled from best available normals related to time of observation, except Hatteras, Key West, Nantucket, and New Orleans, which are 24-hour corrected means.

An intense storm centered near the southern edge of the Labrador peninsula on the 2d and 3d and advanced over the ocean on the following days, first toward the east-northeast, then slightly to the south of east. On the morning of the 5th the center was near 50° N., 40° W., and near here the American steamship *Warrior* noted force 12. For a day or two longer the storm remained intense, moving rather slowly, then it turned toward the northeast with greater speed but decreased strength.

Another important LOW entered the ocean likewise well to northward, the time being over a week later; this storm was central to northeastward of Newfoundland on the 12th, and became part of an extensive LOW system, reaching a long distance from west to east. By the 14th the eastern portion of this system had become very intense near 50° N., 20° W., and from this vicinity it moved slowly northeastward, remaining very violent, until the 17th, when it showed a lessening of force, and soon separated into two parts. The northeastern part moved away to the waters east of Iceland, while the southwestern part, remaining near the British Isles, largely filled up during the next few days.

Two vigorous storms affected the western part of the North Atlantic about this time, notably in lower latitudes than those previously described. The earlier of these was near Hatteras on the 16th, and traveled toward the east-northeast. By the evening of the 17th, near 40° N., 48° W., it had become stronger than before and within the next two days it had advanced to 55° N., 23° W., continuing very intense. The course then changed to northward and the LOW was near Iceland by the evening of the 20th. The second of these lower-latitude storms was central near the entrance of Chesapeake Bay on the 18th, and had reached the southeast portion of the Grand Banks by the later hours of the 19th. The 21st found this second storm near Ireland, as the southern part of a large LOW system.

This stormy period from about the 14th to 22d resulted in several ship disasters, chiefly to eastward of the 35th meridian. The Norwegian motor tanker *Jaguar*, from Minatitlan for Germany, broke in two suddenly on the 18th, near 35° N., 46° W., but apparently all the crew were rescued. The after part floated for about a fortnight, to 35° N., 32° W., where it was picked up and towed to Fayal. From large seagoing vessels remote from land three men were lost overboard, the Norwegian motor tanker *Glittre* losing the first officer. Close to shore many lives were lost from smaller craft sinking or from upsetting of small boats attempting rescue.

Numerous vessels which made port safely with crews intact suffered minor structural damage, or loss or smashing of their small boats. The table of gales shows several cases during these days of vessels encountering force 12 or force 11. Charts XIII, XIV, and XV present the conditions respectively on the 17th, 18th, and 19th.

The morning of the 22d showed a strong LOW central north of Lake Ontario, in connection with which a secondary developed to the southward. This LOW system resulted in gales which were experienced by vessels on the western part of the ocean during the next few days, as it advanced northeastward. One report of force 12, from the American tanker *H. D. Collier*, is connected with this LOW.

A succeeding storm of marked strength was centered on the forenoon of the 25th near the Bay of Fundy (see chart XVI.) This took a course at first northeastward then later northward. The Dutch steamship *Simaloer* reported hurricane-force wind resulting from it when the vessel was between Bermuda and Nantucket.

Fog.—An extensive search in records for the North Atlantic has brought to notice no earlier month with as little fog as the reports at hand show for January 1939. From regions to eastward of the 45th meridian not a single mention has come, though the area between the British Isles and the Azores had experienced considerable fog during the latter part of the month preceding.

Over waters between Nova Scotia and Hatteras a little fog was encountered in January, largely during the final three days. The 5°-square, 35° to 40° N., 70° to 75° W., furnishes reports of fog on 6 days, or more days than for December 1938. This square leads in the month's fog occurrence on the North Atlantic Ocean proper. Only on the 12th and the 16th was fog met in the Grand Banks area.

For the Gulf of Mexico only one of the 5°-squares has yielded reports of fog; that square was the northwestern district, 25° to 30° N., 90° to 95° W., which is the foggiest portion of the Gulf. There the data show 9 days of fog, almost all of them during the first fortnight of the month.

ADDITIONAL NOTE ON THE WEST INDIAN HURRICANE OF AUGUST 23–28, 1938

Mr. R. A. Dyke, forecaster at the Weather Bureau office, New Orleans, La., has recently received and has submitted some interesting material from the Mexican Meteorological Service, Tacubaya, D. F., regarding the West Indian hurricane of August 23–28, 1938, that passed over Yucatan on the 25–26th and died out near central Mexico. The following extract is from a letter received by Mr. Dyke:

> The track of the storm, we believe, passed exactly over Progreso, since there was observed a calm of about 15 minutes and the wind backed from north to south by way of west.
>
> In Ciudad Victoria the cyclonic winds began at hour 2000 on the 27th, but it was not until the 28th, between 1100 and 2000, that the wind reached its maximum, causing great damage. The precipitation was extraordinarily abundant in the north sector of the storm and rather scant in the south, and although this is normal the difference was very remarkable in this cyclone.
>
> In Zacatecas the wind backed on the 30th, with a falling barometer. The great mass of clouds crossed the country and reached the Pacific coast.

Figure 1 is from a photostat of a self-registering wind pressure gage at Progreso, Yucatan, showing the intensity and gustiness of the northerly winds before, and the southerly winds after, the passage of the calm center on August 26. Note the light winds to calm at the center.—*W. E. Hurd.*

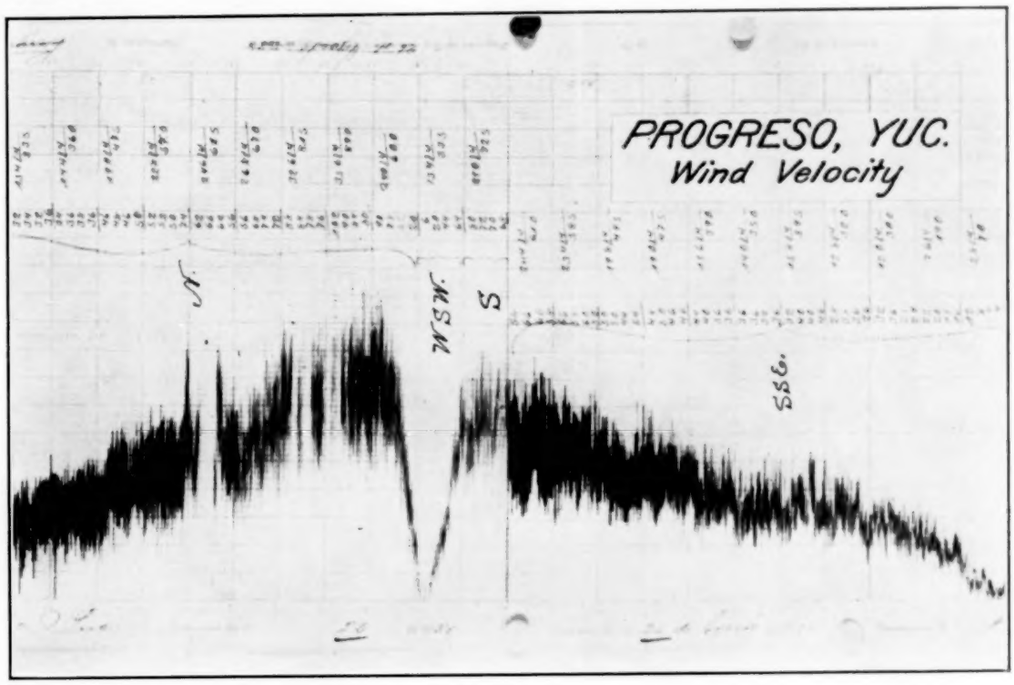

FIGURE 1.

OCEAN GALES AND STORMS, JANUARY 1939

Vessel	Voyage		Position at time of lowest barometer		Gale began January	Time of lowest barometer, January	Gale ended January	Lowest barometer	Direction of wind when gale began	Direction and force of wind at time of lowest barometer	Direction of wind when gale ended	Direction and highest force of wind	Shifts of wind near time of lowest barometer
	From—	To—	Latitude	Longitude									
NORTH ATLANTIC OCEAN			° ′	° ′				*Inches*					
Bronxville, Nor. M. S.	Gothenburg	New York	42 15 N.	63 52 W.	[1]31	8a, 1	[1]31	29.92	S	W, 4	NW	S, 9	
Laurent Meeus, Belg. M. S.	Texas City	Holehsven	[2]47 22 N.	32 43 W.	1	10p, 1	4	29.62	SSE	SSE, 10	W	SSE, 10	SSE-WSW.
American Merchant, Am. S. S.	London	New York	47 00 N.	36 30 W.	5	5a, 5	7	28.88	SSE	S, 10	NW	NW, 11	SSE-SW.
American Shipper, Am. S. S.	New York	Liverpool	49 03 N.	30 00 W.	5	2p, 5	7	29.08	SE	SSE, 10	SSW	SSE, 10	SE-SSW.
Scanpenn, Am. S. S.	do	Gothenburg	52 17 N.	41 54 W.	5	4p, 5	7	28.58	NE	NNE, 11	NW	NNE, 11	None.
Warrior, Am. S. S.	St. John, N. B.	London	47 32 N.	41 17 W.	5	Mdt. 5	7	28.75	WNW	WNW, 10	NW	W, 12	W-WNW.
Collamer, Am. S. S.	Havre	New York	45 08 N.	20 22 W.	6	6a. 8	8	29.65	SSW	WSW, 3	WSW	S, 10	WSW-W.
Vincent, Am. S. S.	Dundee	do	34 15 N.	50 05 W.	9	Mdt. 9	10	29.75	WSW	W, 8	NW	NW, 9	WSW-NW.
Georgia, Dan. S. S.	Gothenburg	Boston	52 30 N.	41 40 W.	12	Noon, 13	14	28.35	E	E, 8	SW	E, 9	E-SW.
Collamer, Am. S. S.	Havre	New York	43 39 N.	47 18 W.	12	Noon, 13	14	29.04	W	W, 8	W	W, 10	Westerly.
Black Hawk, Am. S. S.	New York	Antwerp	50 26 N.	20 15 W.	14	2p, 14	16	28.15	ENE	S, 8	WSW	SW, 10	SSE-SW.
Amsterdam, Du. S. S.	Hamburg	Baton Rouge	46 40 N.	14 00 W.	14	3p, 14	15	28.65	SSW	SSW, 10	W	W, 11	SW-W.
Steelmaker, Am. S. S.	Avonmouth	Portland, Me.	[2]48 52 N.	10 36 W.	14	9p, 14	15	28.52	S	W, 10	WSW	W, 12	SSW-W.
Black Tern, Am. S. S.	Rotterdam	New York	49 30 N.	21 30 W.	14	4a, 15	16	28.16	SW	SW, 10	WNW	SW, 10	SW-WSW.
Laurent Meeus, Belg. M. S.	Killingholme	Corpus Christi	48 29 N.	8 49 W.	14	Noon, 15	16	28.70	SW	SSW, 9	WSW	SSW, 12	S-SW.
Robin Goodfellow, Am. S. S.	Trinidad	New York	35 12 N.	71 54 W.	16	1p, 16	17	29.58	WSW	WSW, 10	NW	W, 11	SW-W.
West Cohas, Am. S. S.	Manchester	Beaumont	40 12 N.	26 50 W.	16	2p, 16	17	29.12	SW	W, 11	W	W, 11	SW-W.
San Bruno, Pan. S. S.	St. John, N. B.	Kingston	35 15 N.	69 20 W.	16	6p, 16	17	28.91	E	WNW, 10	NNW	NW, 12	SW-NW.
Soekaboemi, Du. S. S.	St. Vincent	Halifax	[2]39 16 N.	53 10 W.	17	4p, 17	18	28.53	SE	WSW, 6	NW	SSE, 12	S-WSW-NW.
Adria, Ger. M. S.	London	Savannah	35 06 N.	55 48 W.	17	4p, 17	18	29.48		NW, 12		NW, 12	
Exminster, Am. S. S.	Gibraltar	New York	36 05 N.	48 40 W.	17	4p, 17	18	29.02	S	SW, 12	NW	WSW, 12	SW-W.
Teresa Odero, Ital. M. S.	Houston	Gibraltar	[2]35 23 N.	48 28 W.	17	4p, 17	18	29.20	SSW	SW, 12	W	SW, 12	SW-WSW.
American Importer, Am. S. S.	New York	Liverpool	43 30 N.	45 00 W.	17	4a, 18	19	28.50	ENE	NE, 10	WNW	NNW, 12	NE-NNW.
American Merchant, Am. S. S.	do	London	45 12 N.	41 36 W.	17	8a, 18	19	28.39	E	SE, 6	NW	W, 12	SE-NE-NW.
Statendam, Du. S. S.	Curacao	New York	36 00 N.	72 42 W.	18	9p, 18	19	29.38	S	W, 9	N	W, 9	SW-NW.
Soekaboemi, Du. S. S.	St. Vincent	Halifax	42 02 N.	58 40 W.	18	8a, 19	19	29.26		NNE, 10		NNE, 10	
Breedijk, Du. S. S.	Rotterdam	Boston	50 46 N.	23 46 W.	19	9a, 19	20	28.25	SSE	WSW, 11	W	WSW, 12	SW-WSW.
Black Eagle, Am. S. S.	Antwerp	New York	50 10 N.	24 10 W.	18	8p, 19	20	28.54	SSE	SSW, 11	W	WSW, 12	SSW-NW.
Steelmaker, Am. S. S.	Avonmouth	Portland, Me.	[2]46 14 N.	18 22 W.	19	9p, 19	20	29.33	SSW	S, 12	W	S, 12	S-W.
Laurent Meeus, Belg. M. S.	Killingholme	Corpus Christi	[2]44 39 N.	19 44 W.	18	9p, 19	20	29.51	S	SW, 12	SW	SW, 12	SW-WNW.
Svanhild, Dan. S. S.	Copenhagen	Houston	[2]46 59 N.	12 13 W.	20	4a, 21	21	29.24	SW	WSW, 9	NW	WSW, 11	WSW-WNW.
Black Eagle, Am. S. S.	Antwerp	New York	48 33 N.	34 00 W.	21	4p, 21	21	28.75	S	SSW, 8	N	N, 11	SSW-N.
Manhattan, Am. S. S.	Cobh	do	49 36 N.	28 06 W.	21	9p, 21	22	28.74	SSW	SW, 9	NNW	WNW, 12	SSW-WNW.
American Importer, Am. S. S.	New York	Liverpool	50 50 N.	14 00 W.	21	8a, 22	23	28.99	S	WSW, 9	NW	W, 11	SSW-WSW.
Coamo, Am. S. S.	San Juan	New York	37 07 N.	72 50 W.	22	3p, 22	23	29.49	W	W, 10	NW	W, 10	W-NW.
H. D. Collier, Am. S. S.	Cristobal	Providence	36 00 N.	72 22 W.	22	4p, 22	23	29.62	SW	W, 12	NNW	W, 12	SW-WNW.
Vito, Nor. M. S.	Gibraltar	Boston	40 55 N.	58 00 W.	22	3a, 23	23	28.98		S, 11	NW	S, 11	S-W.
Gulfking, Am. S. S.	Port Arthur	Beverly, Mass.	34 30 N.	75 17 W.	24	Mdt. 24	25	29.72	WSW	W, 9	WNW	NW, 10	WSW-WNW.
Black Eagle, Am. S. S.	Antwerp	New York	43 06 N.	50 18 W.	25	Noon, 25	26	29.06	S	S, 9	WNW	W, 11	S-WSW.
Simaloer, Du. S. S.	Dakar	Boston	35 45 N.	64 39 W.	24	Noon, 25	26	29.56	S	W, 10	WNW	SSW, 12	SSW-W.
Bienville, Am. S. S.	Mobile	London	39 15 N.	57 15 W.	25	8p, 25	26	29.42	S	S, 11	W	S, 11	S-WNW.
Sarcoxie, Am. S. S.	Dundee	New York	53 30 N.	35 00 W.	28	1a, 29	29	29.15	SSE	SE, 10	NW	SE, 10	SE-W-NW.
Normandie, Fr. S. S.	Southampton	do	[2]48 06 N.	31 59 W.	30	3p, 30	30	28.73	SE	WNW, 8	WNW	WNW, 10	ESE-WNW.
Bienville, Am. S. S.	Mobile	London	46 54 N.	32 10 W.	29	Mdt. 30	30	29.22	N	WNW, 5	W	NW, 12	W-WNW.
General Gassouin, Fr. M. S.	Gibraltar	Philadelphia	37 13 N.	65 22 W.	30	Noon, 31	[4]1	[3]29.33	SW	WSW, 10	NW	W, 10	SW-W.
NORTH PACIFIC OCEAN													
Genyo Maru, Jap. M. S.	Kobe	Los Angeles	43 58 N.	167 17 W.	1	3a, 1	1	28.56	N	N, 6	W	WNW, 8	ENE-NW.
Toorak, Br. S. S.	Osaka	do	41 30 N.	155 34 E.	1	Noon, 1	2	29.12	WNW	NNW, 10	N	NW, 11	W-NNW-NW.
Swiftsure Bank Lightship, U. S.	On station		48 33 N.	125 00 W.	1	4p, 1	1	29.39	SSE	SSW, 9	SSE	SSE, 9	SE-SSW-S.
Empress of Russia, Br. S. S.	Yokohama	Victoria, B. C.	41 35 N.	153 59 E.	[1]31	Mdt, 1	2	29.78	WNW	NW, 9	NW	NW, 9	
Mauna Ala, Am. S. S.	Seattle	Honolulu	46 12 N.	126 00 W.	2	6p, 2	3	29.08	S	SSW, 9	W	S, 12	S-SW.
Swiftsure Bank Lightship, U. S.	On station		48 33 N.	125 00 W.	2	8p, 2	3	29.07	SE	ESE, 8	SW	SE, 10	SE-ESE-S.
Tai Yang, Nor. M. S.	Yokohama	Los Angeles	[2]41 16 N.	153 59 E.	3	6a, 3	5	29.15	ENE	NE, 10	WNW	N, 11	E-N.
San Luis Maru, Jap. M. S.	Port Costa	Yokohama	33 24 N.	160 35 E.	3	Noon, 3	3	29.36	S	SSW, 10	W	SSW, 10	SSW-WSW.
Empress of Asia, Br. S. S.	Victoria, B. C.	do	42 30 N.	150 00 E.	3	9a, 3	3	29.43	NE	NE, 8	NW	N, 9	ENE-N.
Toho Maru, Jap. M. S.	Yokohama	San Francisco	39 07 N.	165 32 E.	3	6p, 3	3	28.80	SSE	S, 6	S	SSE, 10	SSE-W.
Otowasan Maru, Jap. M. S.	Osaka	Los Angeles	39 48 N.	152 06 W.	3	2p, 3	4	[3]29.57	SW	W, 9	WNW	W, 9	
Genyo Maru, Jap. M. S.	Kobe	do	42 52 N.	147 40 W.	2	4p, 3	5	28.71	S	WSW, 10	NW	W, 12	WSW-W.
Nozima Maru, Jap. M. S.	Yokohama	San Francisco	[2]40 16 N.	150 24 E.	3	6a, 3	5	29.15	NNE	N, 7	WNW	NNW, 10	WNW-NNE.
Bralanta, Nor. M. S.	do	Los Angeles	39 32 N.	154 33 E.	3	1p, 3	5	29.11	NNW	NW, 6	NW	NW, 10	NW-NNW.
Daiiti Ogura Maru, Jap. M. S.	do	San Francisco	37 19 N.	137 36 W.	3	6p, 3	5	29.66	W	SW, 7	NW	W, 8	SW-W.
Daisan Ogura Maru, Jap. M. S.	do	Port San Luis	38 30 N.	162 40 E.	3	3a, 4	5	28.85	SSW	W, 10	WNW	W, 10	WSW-WNW.
Komaki Maru, Jap. M. S.	do	San Francisco	41 56 N.	168 35 W.	3	3a, 4	4	28.84	SSE	SE, 12	S	SE, 12	SE-S.
Empress of Russia, Br. S. S.	do	Victoria, B. C.	[2]48 54 N.	179 08 W.	3	8a, 4	4	28.27	SE	SSE, 3	SE	E, 11	SE-S.
Teiyo Maru, Jap. M. S.	Los Angeles	Yokosuka	34 11 N.	171 58 E.	4	5a, 4	5	29.38	SSW	WSW, 8	WNW	NW, 10	SSW-W.
Saparoea, Du. M. S.	Manila	Portland, Oreg.	26 54 N.	162 06 E.	4	11a, 4	5	29.85		WNW, 7		NW, 8	
Toorak, Br. S. S.	Osaka	Los Angeles	41 44 N.	70 28 E.	3	Noon, 4	5	27.76	SE	W, 5	W	WNW, 11	S-W.
Swiftsure Bank Lightship, U. S.	On station		48 33 N.	125 00 W.	4	1p, 4	4	29.43	ENE	ENE, 9	ENE	ENE, 9	
Mauna Ala, Am. S. S.	Seattle	Honolulu	43 24 N.	128 36 W.	3	9p, 4	5	29.11	SSE	SW, 4	NNW	SE, 11	SSW-WSW.
Toho Maru, Jap. M. S.	Yokohama	San Francisco	[2]41 33 N.	177 10 E.	4	2a, 5	6	28.35	SW	W, 8	W	W, 9	WSW-W.
Gefion, Nor. M. S.	Richmond, Calif.	Yokohama	31 43 N.	171 38 W.	4	4p, 4	5	29.60	W	SSW, 7	W	W, 9	SW-W.

[1] December. [2] Position approximate. [3] Barometer uncorrected. [4] February.

OCEAN GALES AND STORMS, JANUARY 1939—Continued

Vessel	Voyage		Position at time of lowest barometer		Gale began January	Time of lowest barometer, January	Gale ended January	Lowest barometer	Direction of wind when gale began	Direction and force of wind at time of lowest barometer	Direction of wind when gale ended	Direction and highest force of wind	Shifts of wind near time of lowest barometer
	From—	To—	Latitude	Longitude									
NORTH PACIFIC OCEAN—Continued			° ′	° ′				Inches					
Pleasantville, Nor. M. S.	Hong Kong	Los Angeles	36 29 N.	151 45 E.	4	Noon, 5	5	29.33	SSW	SW, 11	WNW	SW, 11	SW-WNW.
Makiki, Am. S. S.	Hilo	San Francisco	36 18 N.	125 48 W.	5	4p, 5	5	29.79	W	W, 8		W, 8	
San Luis Maru, Jap. M. S.	Port Costa	Yokohama	33 39 N.	154 20 E.	5	6a, 6	6	29.28	SSW	W, 7	WSW	SW, 10	WSW-W.
Toorak, Br. S. S.	Osaka	Los Angeles	41 43 N.	173 28 W.	5	2p, 6	6	28.58	SSW	S, 9	WSW	S, 10	
Pleasantville, Nor. M. S.	Hong Kong	do	38 35 N.	156 44 E.	6	4p, 6	8	29.17	N	NW, 11	WNW	W, 12	WNW-NW-W.
Brasanta, Nor. M. S.	Yokohama	do	39 25 N.	170 30 E.	6	6p, 6	8	28.98	SW	SW, 9	NW	W, 10	
Talthybius, Br. S. S.	Vancouver, B. C.	Yokohama	49 56 N.	179 43 E.	6	3a, 8	8	28.04	ESE	SSE, 7	SE	SSE, 9	SSE-E.
Nozima Maru, Jap. M. S.	Yokohama	San Francisco	47 18 N.	178 30 E.	7	Noon, 7	7	28.22	SSW	SSW, 7	S	SW, 10	E-SSW-S.
Shoyo Maru, Jap. S. S.	do	do	[1]40 26 N.	161 39 E.	6	6a, 7	8	28.99	W	W, 10	W	W, 12	
Saparoea, Du. M. S.	Manila	Portland, Oreg.	32 54 N.	169 06 W.	8	1p, 8	8	29.85		W, 8		W, 8	
Lacklan, Br. S. S.	Shanghai	Miri, Sarawak	[1]14 54 N.	119 02 E.	7	Mdt., 9	9	29.95	N	NNE, 3	NE	NE, 10	
Pleasantville, Nor. M. S.	Hong Kong	Los Angeles	38 53 N.	174 30 E.	9	8p, 9	10	29.13	SSE	SSW, 11	SW	WSW, 11	S-SW.
Pres. Pierce, Am. S. S.	Honolulu	Yokohama	32 22 N.	154 50 E.	12	2a, 13	14	29.26	SW	W, 11	NW	W, 12	SW-WNW.
Talthybius, Br. S. S.	Vancouver, B. C.	do	40 24 N.	148 54 E.	13	4a, 13	14	29.37	NNW	NNW, 8	NW	N, 9	
Grete Maersk, Dan. M. S.	Los Angeles	do	31 20 N.	166 07 E.	12	11a, 13	15	29.40	SE	SW, 8	WNW	W, 10	SSW-W.
Gefion, Nor. M. S.	Richmond, Calif.	do	32 17 N.	158 58 E.	13	5a, 13	14	29.33	W	W, 8	W	W, 10	
Hoyo Maru, Jap. M. S.	Los Angeles	Kobe	33 12 N.	169 06 E.	14	11a, 14	15	29.53	W	WSW, 6	W	W, 10	WSW-W.
Swiftsure Bank Lightship, U. S.	On station		48 33 N.	125 00 W.	14	11p, 14	15	29.89	W	W, 6	WNW	WSW, 8	SSW-W.
Do.	do		48 33 N.	125 00 W.	16	5a, 17	17	29.83	E	S, 6	SW	WSW, 8	SE-WSW.
Hoyo Maru, Jap. M. S.	Los Angeles	Kobe	33 06 N.	159 30 E.	17	10p, 17	18	29.92	W	W, 8	NW	NW, 9	W-NW.
Swiftsure Bank Lightship, U. S.	On station		48 33 N.	125 00 W.	18	7a, 18	19	29.72	ESE	SSW, 7	S	SW, 8	E-SSW.
Raby Castle, Br. M. S.	Los Angeles	Yokohama	35 06 N.	177 00 E.	21	Mdt, 21	22	30.02	SW	SW, 8	WNW	WSW, 9	SW-NW.
Empress of Russia, Br. S. S.	Victoria, B. C.	do	51 14 N.	140 27 W.	22	Noon, 23	24	29.10	S	SW, 8	SW	W, 9	S-WNW.
Niel Maersk, Dan. M. S.	Yokohama	Los Angeles	42 54 N.	145 42 W.	25	2a, 25	25	29.77	WNW	NNW, 4	WSW	WSW, 9	SE-NNE-NW.
Alnbaman, Am. S. S.	Balboa	do	15 28 N.	94 02 W.	25	3p, 25	26	29.82	WNW	NW, 7	NE	NW, 11	WNW-NW.
Swiftsure Bank Lightship, U. S.	On station		48 33 N.	125 00 W.	25	4p, 26	26	29.64	ENE	S, 6	S	ENE, 9	SE-SSW.
Mauna Ala, Am. S. S.	Honolulu	Portland, Oreg.	44 18 N.	128 00 W.	27	6p, 28	28	29.46	WNW	S, 8	W	WNW, 8	S-SSE-W.
Swiftsure Bank Lightship, U. S.	On station		48 33 N.	125 00 W.	28	2a, 29	29	29.43	ESE	SE, 7	WSW	ESE, 8	ESE-WSW.

[1] Position approximate.

NORTH PACIFIC OCEAN, JANUARY 1939

By WILLIS E. HURD

Atmospheric pressure.—Throughout the Aleutian region and eastward to the northern coast of British Columbia, pressure in January 1939 was much below the normal of the month. At Juneau the average barometer, 29.66, showed a departure of −0.22 inch. The Aleutian LOW, average lowest pressure about 29.40 inches, was central from the western part of the Gulf of Alaska to middle Aleutian waters. Along the northern and middle routes barometer readings well below 29 inches occurred on a number of days, particularly during the first third of January. The lowest reading, 27.76 inches, was made on board the British steamship *Toorak*, near 41° N., 171° E., on the 4th.

TABLE 1.—*Averages, departures, and extremes of atmospheric pressure at sea level, North Pacific Ocean, January 1939, at selected stations*

Station	Average pressure	Departure from normal	Highest	Date	Lowest	Date
	Inches	Inch	Inches		Inches	
Point Barrow	29.97	−0.11	30.44	14	29.18	31
Dutch Harbor	29.41	−.17	30.32	28	28.56	7
St. Paul	29.58	−.05	30.28	17	29.08	2
Kodiak	29.40	−.19	29.98	29	28.68	23
Juneau	29.66	−.22	30.21	25	28.75	2
Tatoosh Island	29.08	.00	30.06	25	29.07	2
San Francisco	30.13	+.02	30.44	24	29.67	5
Mazatlan	29.96	+.01	30.02	4	29.88	23
Honolulu						
Midway Island	30.15	+.12	30.39	21	29.77	4
Guam	29.87	−.03	29.97	12	29.53	28
Manila	29.92	+.03	29.97	4, 12, 15	29.86	6, 14, 30
Hong Kong	30.11	.00	30.28	12	29.98	30, 31
Naha	30.12	+.04	30.33	8	29.86	4
Titijima	30.08	+.07	30.24	16, 17	29.89	11
Petropavlosk	29.66	+.01	30.15	12	29.06	6

NOTE.—Data based on 1 daily observation only, except those for Juneau, Tatoosh Island, San Francisco, and Honolulu, which are based on 2 observations. Departures are computed from best available normals related to time of observation.

Anticyclones were unstable as to position and area, but on the average occupied a band extending from California across Midway Island to the China coast. At Midway Island the average pressure, 30.15 inches, was 0.12 inch above the normal.

Cyclones and gales of the extratropics.—The early part of January may be characterized as one of the stormiest periods in recent years on the North Pacific Ocean. At the opening of the month low pressure extended across the northern half of the ocean, with three distinct and powerful centers, one east of Japan, another in upper middle longitudes, and a third off the west coast of the United States and British Columbia. In connection with these specific storms and the generally unsettled weather existing generally to the northward of the 30th parallel during the 1st to 5th gales, many of which were of hurricane or near hurricane intensity, occurred over wide areas, some being experienced almost as far south as the 25th parallel. However, in east longitudes, the greater part of the high winds reported occurred between latitudes 30° and 45° N., and in west longitudes, between 35° and 45° N., except along the American coast, where they were experienced also in much higher latitudes.

The easternmost Pacific storm was of unusual severity. It was damaging on the Washington, Oregon, and California coast, from the standpoint of both heavy winds and high seas, which continued with varying intensity from the 1st to the 5th. At the entrance of the Strait of Juan de Fuca, the Swiftsure Bank Lightship reported winds of forces 9 to 10 on the 1st, 2d, and 4th. At sea several vessels were delayed in passage, and a number of passengers on the American steamship *Lurline* were injured, according to press reports, when a huge sea swept the decks. The American steamship *Mauna Ala* reported southerly winds of forces 11 to 12 on the 2d and 4th while

proceeding southwestward some 100 to 200 or more miles west of the Oregon coast, lowest barometer 29.08 inches, on the 2d. Much farther at sea, near 43° N., 148° W. the Japanese motorship *Genyo Maru* encountered strong gales to hurricane winds, lowest barometer 28.71, on the 3d.

In connection with the midocean cyclone of this period in January, abnormally low pressures were recorded over a considerable region south of the Aleutians. Readings close to 28 inches were had on several ships, with an accompaniment of strong to storm gales (forces 9 to 11). The British steamship *Toorak*, already mentioned as having a barometer reading of 27.76 inches on the 4th, encountered the full strength of the wind in a northwesterly gale of force 11 near 42° N., 176° E., on the 5th. Stormy conditions, with wind forces of 8 to 10, continued through the 6th within the region of about 40° to 50° N., 175° E. to 170° W., but thereafter abated.

The early January cyclone east of Japan was of practically equal intensity and extent to those previously mentioned, except that the barometer did not fall to similar depths. On the 1st and 2d the British steamship *Toorak*, and on the 3d the Norwegian motorship *Tai Yang*, experienced northerly gales of force 11 within the locality, 41°–42° N., 153°–156° E. Outside the immediate locality gales of force 8 to 10 occurred over a wide stretch of sea from near the coast of Japan, on to the eastward, where the storm area merged with that prevailing in middle longitudes.

Widespread low pressure continued through the 10th over the western half of the ocean, with much stormy weather. In fact, during the first third of the month, fully three-fourths of January's gales occurred. The 7th was the day of most intense winds, with hurricane forces experienced by the Norwegian motorship *Pleasantville* near 38½° N., 156½° E., and by the Japanese steamship *Shoyo Maru* near 40½° N., 161½° E.

Following the 10th storm energy had greatly subsided, so that, up to the 15th, only scattered gales were reported. The one intense wind of the period thus far coming to attention was a west gale of force 12, encountered by the American steamship *President Pierce* on the 13th near 32° N., 155° E.

The North Pacific, during the final half of the month, was unusually free of gales for January, and such as were reported on extratropical waters for the 16th to 31st did not exceed 9 in force. Those particularly to be noticed were observed as follows on the Swiftsure Bank Lightship: Of force 8 on the 17th, 18th, and 28th, and of force 9 on the 25th.

Gales of the Tropics.—The tropical gales reported for the month occurred in two localities—the Gulf of Tehuantepec and the China Sea. In the Gulf there were Tehuantepecers of force 7 on the 6th, 18th, and 21st. On the 25th, with the crest of an anticyclone lying over the Gulf States and the northern part of the Gulf of Mexico, the consequent Tehuantepecer, as experienced by the American steamship *Alabaman*, attained an intensity of force 11. In the China Sea the British steamship *Lacklan* encountered a northeast gale of force 10, barometer 29.95, near 15° N., 119° E., on the 8th.

Fog.—Very little fog was seen on the North Pacific this month. There were scattered occurrences in northern waters on 4 days early in January, and about midway between California and the Hawaiian Islands, fog was observed on 5 days, mostly near the middle of the month. Ships reported fog on 4 days along the west coast of the United States; on 2 days off Lower California; and 1 day each near Cape Corrientes; in the Gulf of Tehuantepec; and off the coast of Costa Rica.

CLIMATOLOGICAL TABLES

[Climate and Crop Weather Division, J. B. KINCER in charge]

DESCRIPTION OF TABLES AND CHARTS

By J. P. KOHLER

Table 1 presents average and extreme values for 45 climatic districts, based on all available data ascertained by regular and cooperative Weather Bureau stations.

Table 2 gives the data ordinarily needed for climatological studies for about 180 Weather Bureau stations making simultaneous observations at 7:30 a. m. and 7:30 p. m. daily, 75th meridian time, and for about 20 others making only one observation. The altitudes of the instruments above ground are also given.

Beginning with January 1, 1932, all wind movements and velocities published herein are corrected to true values by applying to the anemometer readings, corrections determined by actual tests in wind tunnels and elsewhere.

Table 3 gives, for about 37 stations of the Canadian Meteorological Service, the means of pressure and temperature, total precipitation, depth of snowfall, and the respective departures from normal values, except in the case of snowfall. The sea-level pressures have been computed according to the method described by Prof. F. H. Bigelow in the REVIEW of January 1902, **30**:13–16.

Table 4 lists the severe local storms reported in the United States during the month. It is compiled from reports furnished mostly by officials of the Weather Bureau.

In regard to discussion of charts that follow: Charts I, IV, V, and VI are based on observational data from stations listed in table 2.

Chart I. *Temperature departures and wind roses for selected stations.*—This chart presents the departures of the monthly mean surface temperatures from the monthly normals. The shaded portions of the chart indicate areas of positive departures and unshaded portions indicate areas of negative departures. Generalized lines connect places having approximately equal departures of like sign. Charts of monthly surface temperature departures in the United States was first published in the MONTHLY WEATHER REVIEW for July 1909, and continued thereafter, but smaller charts appear in W. B. *Bulletin U* for 1873 to June 1909. inclusive. An innovation has been made in this chart, beginning January 1939. The selected wind rose data formerly published as chart VII has been transferred to this chart. The wind roses are based on hourly percentages by months for 28 selected Weather Bureau stations.

Chart II.—*Tracks of centers of* ANTICYCLONES; and Chart III.—*Tracks of centers of* CYCLONES. The roman numerals show the chronological order of the centers. The figures within the circles show the days of the month, the location indicated being that at 7:30 a. m., 75th meridian time. Within each circle is also an entry of the last three figures of the highest barometric reading (chart II) or the lowest reading (chart III) the reported at or near the center at that time, in both cases as reduced to sea level and standard gravity. The intermediate 7:30 p. m. locations are indicated by dots. The inset map on chart II shows the departure of monthly mean pressure from normal and the inset on chart III shows the change in mean pressure from the preceding month.

The use of a new base map for charts II and III began with the January 1930 issue.

Chart IV.—*Percentage of clear sky between sunrise and sunset.*—The average cloudiness at each regular Weather Bureau station is determined by numerous personal observations between sunrise and sunset. The difference between the observed cloudiness and 100 is assumed to represent the percentage of clear sky, and the values thus obtained are the basis of this chart. The chart does not relate to the night hours.

Chart V.—*Total precipitation.*—The scales of shading with appropriate lines show the distribution of the monthly precipitation according to reports from both regular and cooperative observers. The inset on this chart shows the departure of the monthly totals from the corresponding normals, as indicated by the reports from the regular stations.

Chart VI.—*Isobars at sea level and isotherms at surface, prevailing winds.*—The pressures have been reduced to sea level and standard gravity by the method described by Prof. Frank H. Bigelow in the REVIEW for January 1902, **30**:13–16. The pressures have also been reduced to the mean of the 24 hours by the application of a suitable correction to the mean of 7:30 a. m. and 7:30 p. m. readings at stations taking two observations daily, and to the 7:30 a. m. or the 7:30 p. m. observation at stations taking but a single observation.

The diurnal corrections so applied, except for stations established since 1901, will be found in the Annual Report of the Chief of the Weather Bureau, 1900–1901, volume 2, table 27, pages 140–164.

The sea-level temperatures are now omitted and average surface temperatures substituted. The isotherms cannot be drawn in such detail as might be desired, for data from only the regular Weather Bureau stations are used.

The prevailing wind directions are determined from hourly observations at almost all the stations. A few stations determine their prevailing directions from the daily or twice-daily observations only.

Chart VII.—*Total snowfall.*—This is based on the reports from regular and cooperative observers and shows the depth in inches of the snowfall during the month. In general, the depth is shown by lines connecting places of equal snowfall, but in special cases figures also are given. This chart is published only when the snowfall is sufficiently extensive to justify its preparation. The inset on this chart, when included, shows the depth of snow on the ground at 7:30 p. m. of the Monday nearest the end of the month and is a copy of the snow chart appearing in the snow and ice bulletin for that week. Generally, the publication of the Weekly Snow and Ice Bulletin commences about the middle of December and continues to near the close of March.

Charts VIII–XII.—Aerological charts, for description and explanations, see p. 22, of this REVIEW.

Charts, XIII–XIV, etc.—*North Atlantic weather maps for particular days.*

CONDENSED CLIMATOLOGICAL SUMMARY

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course, the number of such records is smaller than the total number of stations.

TABLE 1.—*Condensed climatological summary of temperature and precipitation by sections, January 1939*

Section	Temperature								Precipitation					
	Section average	Departure from the normal	Monthly extremes						Section average	Departure from the normal	Greatest monthly		Least monthly	
			Station		Date	Station	Lowest	Date			Station	Amount	Station	Amount
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	51.0	+4.6	Greensboro	80	4	2 stations	21	1 1	4.81	−0.03	Haleyville	8.72	Mobile Airport	2.06
Arizona	42.0	+.2	Florence	81	20	do	−2	1 17	1.12	−.19	Bright Angel Ranger Station.	4.13	Gould's Ranch	.03
Arkansas	45.5	+4.1	Arkadelphia	83	1 7	Grannis	12	16	6.21	+1.74	Arkansas City	11.94	Waldron	1.78
California	44.5	−.1	La Mesa	81	19	South Lake	−2	7	3.23	−1.52	Crescent City (near)	11.87	Greenland Ranch	.33
Colorado	25.9	+1.9	3 stations	72	2	Dillon	−29	26	1.30	+.53	Telluride	5.66	Buena Vista	.04
Florida	60.8	+1.6	2 stations	89	1 5	Bushnell	23	26	1.62	−1.13	Panama City	4.05	Belle Glade	.11
Georgia	49.6	+2.4	Waycross	85	4	Blairsville	11	23	3.77	−.49	Dahlonega	7.68	Savannah No. 1	1.17
Idaho	27.7	+3.7	Boise	61	1	Tetonia	−27	26	1.69	−.49	Deception Creek	8.50	Barton Flat	.12
Illinois	34.5	+6.6	Sparta	71	3	Havana	−2	31	3.13	+1.37	Brookport	6.56	New Boston	.69
Indiana	34.6	+5.4	Shoals	75	9	Goshen	1	23	4.12	+.96	Martinsville	9.00	Winona Lake	1.95
Iowa	28.7	+10.1	2 stations	69	2	2 stations	−12	16	.86	−.23	Grundy Center	1.61	Rock Rapids	.24
Kansas	38.3	+8.4	do	76	2	Oberlin	−1	15	.78	+.11	Pittsburg	4.33	Wakeeney	.16
Kentucky	40.4	+4.4	Hopkinsville	74	9	4 stations	11	1 23	5.55	+.98	Calhoun	9.51	Jenkins	3.05
Louisiana	55.4	+3.5	Port Sulphur	83	22	Dodson	22	16	5.62	+.68	Winnfield	17.94	2 stations	1.49
Maryland-Delaware	35.1	+1.4	Cumberland, Md	69	10	Oakland, Md	−7	28	3.58	+.28	Millsboro, Del	4.74	Chewsville, Md	2.40
Michigan	23.8	+3.0	Monroe	60	6	2 stations	−35	25	2.23	+.34	Delaware	5.13	Evart	1.01
Minnesota	15.2	+5.9	Winona	52	9	Warroad	−41	16	1.22	+.45	Pigeon River Bridge	2.74	Mahnomen	.32
Mississippi	50.5	+3.0	Columbia	81	8	Batesville	21	27	6.84	+1.64	Greenville	15.40	Biloxi	1.34
Missouri	39.0	+8.0	3 stations	74	1 7	Tarkio	−5	16	2.74	+.34	Caruthersville	5.95	2 stations	.71
Montana	28.5	+8.9	2 stations	62	1 1	Outlook	−28	17	.70	−.24	Heron	5.84	do	T
Nebraska	32.1	+8.9	3 stations	73	2	2 stations	−8	1 15	.70	+.18	Hay Springs	1.65	Virginia	.16
Nevada	32.4	+3.0	Las Vegas	74	24	Ely	−10	31	.96	−.22	Marlette Lake	5.38	Mina	.20
New England	21.9	−.8	2 stations	58	1 10	Enosburg Falls, Vt	−34	27	2.69	−.82	Nantucket, Mass	5.89	Enosburg Falls, Vt	.92
New Jersey	30.9	.0	Elizabeth	65	6	Layton	−10	20	3.98	+.41	Atlantic City	5.65	Layton	1.98
New Mexico	33.3	−.3	Hobbs	82	22	Eagle Nest	−30	12	1.39	+.81	Irving's Ranch	4.99	2 stations	.00
New York	23.5	+.2	Geneva	61	10	Stillwater Reservoir	−38	27	2.86	−.11	Bridgehampton	4.61	Whitehall	1.02
North Carolina	43.6	+1.9	Kinston	80	10	Mount Mitchell	2	27	3.98	+.18	Highlands	8.19	Louisburg	1.65
North Dakota	15.0	+8.7	New England	55	8	2 stations	−32	1 15	.47	−.01	Fullerton	1.36	Mayville	.06
Ohio	33.4	+4.8	Gallipolis (near)	69	5	Canfield	−4	26	2.78	−.34	Portsmouth No. 2	4.60	Sidney	1.20
Oklahoma	44.3	+5.9	Kenton	78	2	Eagle Nest	11	16	2.79	+1.34	Hobart	4.65	Hooker	1.10
Oregon	34.7	+3.0	Wolf Creek	70	1	2 stations	−12	31	2.90	−.94	McNamurs	16.36	Lake	.10
Pennsylvania	30.3	+1.8	Uniontown	69	4	Gouldsboro	−18	28	3.14	−.12	Mt. Pocono	5.93	Meadville	1.38
South Carolina	48.2	+2.3	Beaufort (near)	81	1 10	Longcreek (near)	15	1 23	3.10	−.48	Caesars Head	7.17	Orangeburg	1.11
South Dakota	25.7	+8.9	4 stations	65	1 1	La Delle (near)	−20	21	.95	+.39	Miller	2.88	McLaughlin	T
Tennessee	42.8	+3.5	3 stations	74	1 8	Erwin	13	28	6.05	+1.11	Savannah	9.75	Elizabethton	2.33
Texas	50.9	+2.7	Raymondville	88	10	Muleshoe	13	1 1	3.10	+1.41	Liberty	10.73	El Paso	.65
Utah	26.5	+1.4	St. George	61	27	Woodruff	−14	9	1.37	+.16	Silver Lake (Brighton)	4.13	Manila	.06
Virginia	39.3	+2.6	Clarksville	73	4	3 stations	5	1 27	3.35	+.02	Onley	5.17	Halifax	2.28
Washington	36.2	+5.8	Walla Walla	67	1	do	0	1 25	5.79	+.19	Wynoochee Oxbow	28.41	Rock Island	.34
West Virginia	35.4	+3.6	Spencer	80	4	Rainelle	−7	28	3.59	−.11	Pickens	11.63	Romney	1.68
Wisconsin	21.9	+6.8	2 stations	57	1 9	Long Lake	−34	25	1.87	+.62	Plum Island	4.53	Hatfield	.53
Wyoming	24.0	+4.0	Torrington	68	1	Moran	−29	22	.78	−.01	Bechler River	5.73	Nine Mile Creek	.41
Alaska (December)	10.9	+6.2	Sitka	53	1	Wiseman	−47	23	3.33	+.90	Little Port Walter	30.46	Ophir	.04
Hawaii	69.7	+1.1	2 stations	89	1 5	Kanalohuluhulu	42	1	9.80	+1.57	Pilsonus	36.00	Kolokaual	.20
Puerto Rico	72.4	−.4	Utuado	92	17	Cayey	47	21	2.14	−1.61	La Mina (El Yunque)	8.54	Ponce	.67

1 Other dates also.

TABLE 2.—*Climatological data for Weather Bureau stations, January 1939*

[Compiled by Annie E. Small, by official authority U. S. Weather Bureau]

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01 inch or more	Wind: Average hourly velocity	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	° *F.*	° *F.*	°*F.*		°*F.*	° *F.*		°*F.*	° *F.*	° *F.*	° *F.*	%	*In.*	*In.*		*Miles*								*0–10*	*In.*	*In.*
New England							**23.9**	**+0.4**										**72**	**2.85**	**−0.6**										**6.6**		
Eastport	75	67	85	29.81	29.90	−0.10	20.8	+0.4	45	10	29	−5	27	13	30	18	12	70	1.57	−2.4	11	13.7	nw.	44	ne.	31	9	6	16	6.3	11.6	3.8
Greenville, Maine	1,069	4	41	28.81	29.94	.....	10.6	−1.6	42	11	21	−21	27	0	42	8	6	...	1.81	−1.1	11	.....	nw.	...	...	...	...	...	...	...	...
Portland, Maine	103	82	117	29.84	29.97	−.08	23.6	+1.2	54	10	32	−1	27	16	27	20	15	65	3.19	−.8	8	7.3	n.	17	nw.	22	14	10	7	4.4	14.5	8.5
Concord	289	54	72	29.65	29.98	−.07	21.8	+.2	54	10	31	−10	27	12	39	...	...	...	3.06	+.1	10	6.3	nw.	27	nw.	23	5	6	20	7.5	18.1	8.1
Burlington	403	11	48	29.54	30.01	−.04	16.8	−2.0	49	10	25	−26	27	8	38	15	11	77	1.29	−.5	15	10.8	n.	34	s.	28	6	3	22	7.7	14.5	8.3
Northfield	876	12	60	29.00	30.00	−.05	15.9	+.7	53	10	28	−28	27	5	42	14	11	84	1.90	−.4	12	7.0	n.	26	sw.	2	5	12	14	6.8	20.1	14.6
Boston [1]	20	33	62	29.94	29.97	−.08	27.8	−.1	55	10	35	4	27	21	30	24	17	64	2.18	−1.4	12	12.7	w.	43	ne.	30	4	8	18	7.3	7.0	5.0
Nantucket	12	14	90	29.95	29.96	−.08	32.6	+1.3	51	2	38	10	23	27	25	30	26	76	5.89	+2.1	12	15.7	w.	46	ne.	30	8	5	18	6.8	7.9	.3
Block Island	26	11	46	29.96	29.99	−.08	31.9	+.9	53	6	38	8	27	26	27	30	25	74	3.32	−.5	14	19.7	w.	56	nw.	23	11	4	16	5.9	4.9	.5
Providence	159	215	251	29.81	30.00	−.06	28.2	+1.0	51	2	35	4	27	21	32	25	19	69	2.30	−1.4	10	13.1	nw.	45	nw.	22	10	4	17	6.4	7.3	2.2
Hartford	159	66	100	29.83	30.01	−.06	27.4	+1.9	51	10	34	2	27	21	30	...	...	...	3.62	−.3	13	9.2	n.	32	nw.	23	5	10	16	7.0	11.8	4.0
New Haven	106	74	153	29.90	30.02	−.06	29.0	+.8	52	2	35	6	26	23	27	26	21	72	4.02	.0	12	9.9	n.	31	w.	25	7	9	15	6.7	8.0	1.8
Middle Atlantic States							**35.0**	**+2.8**										**71**	**3.51**	**+0.3**										**6.8**		
Albany [1]	292	26	40	29.68	30.01	−.06	22.0	−1.1	53	10	30	−8	27	14	32	20	15	73	2.54	+.1	18	10.9	n.	45	nw.	23	2	7	22	8.4	16.4	12.7
Binghamton	871	57	79	29.06	30.02	−.06	26.2	+2.1	57	10	34	−9	27	18	31	23	19	79	2.59	+.1	15	7.3	nw.	30	w.	22	1	7	23	8.7	22.9	11.8
New York	314	415	454	29.67	30.03	−.07	32.3	+1.4	56	6	39	6	27	26	28	29	22	65	3.80	+.1	13	15.6	nw.	63	nw.	22	7	6	18	6.9	9.5	.5
Harrisburg [1]	374	94	104	29.66	30.05	−.05	21.8	+2.8	57	10	39	8	26	24	27	28	23	74	3.06	.0	14	8.3	nw.	38	nw.	22	6	9	16	7.2	15.1	1.0
Philadelphia	114	174	367	29.92	30.05	−.06	34.4	+1.8	59	6	40	12	26	28	25	31	26	71	4.46	+1.2	12	13.1	nw.	41	nw.	25	8	6	17	6.5	11.0	2.0
Reading	323	283	306	29.69	30.06	.....	32.9	+3.5	58	10	40	8	26	26	26	28	21	64	3.44	−.1	13	11.6	nw.	48	nw.	22	8	7	16	6.5	16.1	1.0
Scranton	805	72	104	29.13	30.03	−.06	27.9	+1.3	57	10	35	2	27	21	31	25	20	71	2.65	−.4	13	6.5	nw.	35	nw.	26	3	7	21	7.6	11.5	3.0
Atlantic City	52	37	172	29.98	30.04	−.07	36.0	+3.5	60	6	42	13	27	30	29	32	27	72	5.65	+2.2	13	16.4	w.	54	w.	25	8	4	19	7.0	4.8	1.3
Sandy Hook	22	10	57	30.00	30.02	.....	32.4	+1.1	54	6	37	9	26	28	22	30	22	75	3.68	−.3	14	16.4	w.	54	nw.	22	7	4	20	7.0	13.1	1.0
Trenton	190	89	107	29.84	30.05	.....	31.9	+1.4	58	6	38	10	26	26	29	29	24	71	3.89	+.6	15	9.4	nw.	35	nw.	25	6	7	18	7.1	13.5	1.3
Baltimore	123	100	215	29.92	30.05	−.07	38.0	+4.2	63	9	45	17	27	31	27	32	25	64	3.77	+.3	14	10.6	sw.	45	sw.	22	10	4	17	6.5	8.0	.0
Washington	112	62	85	29.93	30.06	−.07	37.8	+4.4	63	10	45	17	26	30	30	35	26	66	3.41	−.1	11	7.2	n.	34	nw.	22	7	9	15	6.5	6.3	.0
Cape Henry	18	8	54	30.04	30.06	.....	44.6	+4.4	71	10	52	26	28	38	23	40	36	77	4.58	+1.4	10	12.7	nw.	40	nw.	22	11	9	11	5.4	.5	.0
Lynchburg	686	144	184	29.32	30.08	−.05	41.9	+4.4	67	2	51	16	28	33	33	35	27	62	2.92	−.5	10	7.8	sw.	38	nw.	22	8	9	14	6.1	3.3	.0
Norfolk	91	80	125	29.98	30.08	−.05	45.2	+4.6	72	10	53	26	26	37	25	39	34	71	3.93	+.8	9	10.0	w.	34	nw.	22	9	6	16	6.1	9.4	.0
Richmond	144	11	52	29.92	30.08	−.06	42.3	+4.4	68	10	52	17	28	33	30	36	30	69	2.64	−.6	9	8.6	sw.	32	nw.	22	15	6	10	4.9	1.2	.0
Wytheville	2,306	49	55	.....	30.08	−.06	37.2	+4.2	64	4	46	10	28	28	36	...	...	75	2.67	−.4	14	8.8	w.	29	w.	...	9	10	12	.....	6.1	.0
South Atlantic States							**49.6**	**+4.0**										**72**	**2.96**	**−0.6**										**4.8**		
Asheville	2,252	89	104	27.70	30.13	−.02	40.2	+4.8	70	3	51	17	28	29	36	34	29	71	3.94	+.8	14	10.2	nw.	34	se.	5	11	7	13	5.5	1.2	.0
Charlotte	779	63	86	29.24	30.10	−.05	45.8	+4.6	69	4	56	26	28	36	31	39	32	64	3.30	−.7	10	7.9	sw.	30	sw.	30	12	6	13	5.3	.2	.0
Greensboro [1]	886	6	56	29.13	30.09	.....	41.4	.....	70	4	52	16	28	30	38	35	31	73	3.16	.....	9	8.4	sw.	31	sw.	30	14	5	12	4.9	T	.0
Hatteras	11	5	50	30.07	30.09	−.05	50.3	+3.2	70	5	57	32	23	43	24	46	43	80	5.92	+1.5	9	14.6	w.	45	nw.	16	13	11	7	4.6	.0	.0
Raleigh	376	103	140	29.66	30.08	−.05	46.0	+4.9	71	10	55	25	28	37	31	40	35	71	2.73	−.9	9	9.0	nw.	30	nw.	22	13	8	10	4.5	2.0	.0
Wilmington	72	73	107	30.03	30.10	−.04	50.4	+3.9	73	4	61	30	20	40	30	45	41	76	3.23	−.1	13	9.9	nw.	38	nw.	22	14	9	8	4.3	.0	.0
Charleston	48	11	92	30.07	30.12	−.03	52.8	+2.9	76	5	62	36	27	44	24	48	44	77	2.69	−.9	9	10.1	sw.	26	sw.	30	13	9	9	4.8	.0	.0
Columbia, S. C.	347	70	91	29.73	30.12	−.03	49.8	+3.8	75	10	60	27	23	39	30	42	34	62	1.64	−1.8	10	9.4	sw.	35	sw.	30	18	8	8	4.2	.0	.0
Greenville, S. C.	1,040	70	78	28.98	30.10	.....	45.2	+4.9	70	8	55	26	28	35	34	39	33	69	4.88	.0	12	7.3	sw.	31	sw.	30	12	9	10	5.1	T	.0
Augusta	182	62	77	29.91	30.11	−.05	50.5	+3.5	77	10	62	29	23	39	34	43	37	68	1.86	−2.1	8	6.3	nw.	24	w.	30	14	6	11	4.7	.0	.0
Savannah	65	73	152	30.07	30.12	−.03	55.8	+4.4	78	10	66	35	19	45	32	48	44	75	1.17	−1.6	6	11.4	w.	37	w.	24	13	10	8	4.6	.0	.0
Jacksonville	43	86	110	30.09	30.14	−.01	58.4	+3.0	80	10	68	37	26	48	28	51	46	75	1.76	−1.0	5	7.9	s.	27	sw.	30	10	14	7	4.5	.0	.0
Florida Peninsula							**66.0**	**+1.7**										**77**	**1.13**	**−1.2**										**4.8**		
Key West	21	10	64	30.07	30.09	−.01	71.8	+2.3	83	13	77	57	20	67	65	63	80	80	1.73	−.2	7	9.9	ne.	23	nw.	16	11	13	7	5.1	.0	.0
Miami	25	124	168	30.09	30.12	−.01	68.8	+2.3	81	18	75	42	20	63	26	63	60	75	.51	−2.0	5	10.1	se.	25	s.	30	12	8	11	5.2	.0	.0
Tampa	35	88	197	30.10	30.14	+.02	62.6	+2.2	80	7	72	40	29	54	28	56	52	76	1.35	−1.3	4	11.0	n.	40	se.	29	14	10	7	4.0	.0	.0
Titusville	43	5	36	.....	.....	.....	60.8	.0	83	13	73	32	20	49	36	54	52	...	.92	−1.5	7	.....	nw.	...	...	...	14	15	2	.....	.0	.0
East Gulf States							**52.9**	**+3.9**										**73**	**3.65**	**−1.1**										**5.4**		
Atlanta [1]	976	5	72	29.07	30.11	−.04	45.2	+2.6	68	4	55	25	27	35	31	40	36	77	4.04	−.9	12	11.0	nw.	34	s.	5	13	4	14	5.1	.0	.0
Macon	370	79	87	29.73	30.13	−.03	50.2	+3.4	76	4	62	30	28	39	35	43	37	67	2.98	−1.2	11	7.4	nw.	24	se.	29	13	5	13	5.2	.0	.0
Thomasville	273	49	58	.....	.....	.....	.....	.....	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Apalachicola	35	11	.....	30.10	30.14	.....	56.4	+2.7	75	11	64	38	19	48	24	52	49	82	3.20	−.4	7	8.4	se.	26	se.	29	15	8	8	4.5	.....	.....
Pensacola	56	149	185	30.07	30.13	−.01	56.1	+3.6	72	22	63	36	27	49	26	52	48	78	2.51	−1.5	7	13.1	s.	42	s.	29	9	14	8	5.2	.0	.0
Anniston	741	9	.....	.....	.....	.....	.....	.....	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Birmingham	700	11	48	29.35	30.10	−.06	49.4	+4.3	74	9	59	28	27	40	31	43	37	68	4.57	−1.0	13	8.9	nw.	35	sw.	4	13	5	13	5.0	.0	.0
Mobile	57	86	161	30.06	30.12	−.03	55.8	+4.3	78	10	65	37	25	47	26	50	45	74	2.64	−2.2	8	10.4	s.	33	sw.	29	7	17	7	5.3	.0	.0
Montgomery	218	92	105	29.88	30.13	−.03	52.8	+4.6	75	4	63	33	25	43	28	46	40	69	3.25	−2.0	9	8.0	e.	25	sw.	29	10	6	15	5.8	.0	.0
Meridian	375	67	92	29.71	30.12	−.04	51.2	+4.2	77	4	62	30	1	40	34	45	40	73	4.83	−.5	10	7.0	sw.	29	sw.	29	9	7	15	5.8	.0	.0
Vicksburg	247	82	102	29.82	30.09	−.06	52.6	+4.4	76	4	61	31	16	44	27	46	40	68	6.27	+.9	12	9.7	se.	32	s.	4	9	7	15	6.1	.0	.0
New Orleans	53	76	84	30.06	30.12	−.01	59.0	+4.8	80	10	67	40	16	51	26	53	49	76	2.24	−2.1	8	7.6	se.	23	se.	29	11	5	15	5.6	.0	.0
West Gulf States							**52.8**	**+4.9**										**72**	**3.81**	**+0.9**										**5.6**		
Shreveport	249	92	227	29.82	30.09	−.05	52.2	+5.2	72	8	61	29	16	43	30	46	40	69	6.79	+2.9	11	12.2	se.	44	w.	29	11	11	9	5.2	.0	.0
Bentonville	1,303	12	38	28.69	30.08	−.06	42.5	+8.4	68	8	52	18	16	33	33	...	...	...	3.36	+.7	10	8.4	s.	25	sw.	28	13	5	13	.....	5.7	.0
Fort Smith	463	57	82	29.60	30.07	−.07	45.6	+6.1	72	2	56	21	16	36	35	39	33	65	1.97	−.6	10	8.5	e.	22	sw.	21	13	8	10	5.2	.0	.0
Little Rock	357	94	102	29.69	30.08	−.07	46.2	+4.8	70	8	55	25	16	38	31	41	35	68	7.86	+3.1	11	8.9	nw.	30	sw.	21	13	6	12	5.2	.0	.0
Austin	605	68	90	29.43	30.06	.....	53.1	+3.6	75	3	63	29	16	43	39	48	43	72	2.23	+.2	12	7.9	s.	32	nw.	29	12	3	16	5.7	.0	.0
Brownsville	57	88	96	29.96	30.02	.....	64.4	+4.6	82	4	72	46	27	57	25	59	56	80	1.55	.0	9	11.9	se.	30	nw.	29	9	10	12	5.9	.0	.0
Corpus Christi	20	11	78	30.04	30.06	−.04	60.2	+4.2	79	4	66	44	13	54	24	56	53	82	1.78	+.2	11	10.8	s.	31	nw.	29	10	5	16	6.1	.0	.0
Dallas	512	220	227	29.50	30.08	.....	50.7	.....	74	3	60	28	16	42	30	44	37	64	2.75	+.4	9	13.3	se.	60	sw.	8	10	9	12	5.7	.0	.0
Fort Worth	679	92	110	29.34	30.07	−.05	50.8	+5.4	77	3	60	30	27	41	36	...	...	...	2.66	+.6	9	10.6	s.	39	w.	17	11	8	12	5.0	.0	.0
Galveston	54	106	114	30.02	30.08	−.05	57.6	+3.8	73	4	63	41	16	52	19	54	51	82	3.75	+.3	10	11.0	s.	30	w.	29	9	11	11	5.4	.0	.0
Houston	138	157	190	29.94	30.09	.....	57.1	+4.4	78	10	65	34	16	49	26	...	...	...	4.89	+1.2	13	10.6	se.	30	nw.	29	10	6	15	6.2	.0	.0
Palestine	510	64	72	29.55	30.08	−.04	51.7	+3.5	72	3	60	28	16	43	27	45	38	67	5.26	+1.8	12	8.2	s.	27	se.	8	9	7	15	5.7	.0	.0
Port Arthur	34	59	134	30.05	30.08	.....	56.7	.....	74	11	64	35	16	49	24	...	...	...	4.65	+1.0	11	13.2	s.	38	nw.	29	7	10	14	5.9	.0	.0
San Antonio	693	111	301	.....	30.06	−.04	54.6	+2.3	75	4	64	35	16	46	30	...	...	70	2.08	+.6	11	12.0	e.	37	w.	29	11	5	15	.....	.0	.0

[1] Observations taken at airport.

TABLE 2.—*Climatological data for Weather Bureau stations, January 1939*—Continued

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01 inch or more	Wind: Average hourly velocity	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
Ohio Valley and Tennessee	*Ft.*	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	° *F.*	° *F.*	° *F.*		° *F.*	° *F.*		° *F.*	° *F.*	° *F.*	° *F.*	%	*In.*	*In.*		*Miles*								*0–10*	*In.*	*In.*
							39.4	+5.7										73	4.83	+1.0										7.4		
Chattanooga	762	71	214	29.28	30.01	−0.15	45.4	+4.2	71	10	55	27	23	36	35	39	33	66	4.95	−.3	15	8.8	w.	42	sw.	5	12	5	14	5.5	0.0	0.0
Knoxville	995	66	84	29.03	30.10	−.05	42.6	+3.8	70	5	52	23	28	33	31	37	32	71	3.82	−.8	16	6.6	w.	30	sw.	5	10	10	11	5.0	.3	.0
Memphis	399	78	86	29.64	30.07	−.09	46.9	+6.0	72	8	54	30	23	40	26	41	35	66	9.72	+4.9	12	9.1	sw.	29	sw.	30	13	3	15	5.5	.0	.0
Nashville	546	168	188	29.51	30.10	−.06	44.5	+5.9	70	3	53	24	23	36	32	39	34	70	6.80	+2.0	16	10.5	sw.	36	w.	30	10	6	15	6.0	.1	.0
Lexington	989	6					38.0	+5.1	67	3	46	15	23	30	30				5.94	+1.8	17		sw				7	6	18		5.7	.0
Louisville	531	188	234	29.47	30.05	−.09	40.6	+6.2	67	9	48	19	23	33	28	36	31	70	4.42	+.4	12	12.0	s.	35	w.	26	5	6	20	7.5	2.0	.0
Evansville	431	76	116	29.57	30.05	−.09	41.0	+7.5	66	3	48	21	23	34	26	36	31	71	5.32	+1.6	11	10.7	sw.	33	sw.	5	5	4	22	7.6	3.5	
Indianapolis	822	194	230	29.12	30.03	−.09	35.9	+7.5	60	9	42	15	22	30	24	32	28	75	5.33	+2.4	13	8.9	s.	31	nw.	22	1	7	23	8.8	7.2	.0
Terre Haute	575	63	149	29.38	30.01		36.8		64	3	44	14	19	30	27	33	30	79	5.16	+2.5	12	10.4	se.	32	w.	24	5	5	21	7.6	14.7	.0
Cincinnati	627	11	51	29.35	30.04	−.08	37.7	+7.4	64	3	45	14	23	30	36	34	30	76	3.77	+.3	12	9.2	sw.	30	w.	22	2	5	24	8.5	6.5	.0
Columbus	822	90	210	29.13	30.03	−.08	35.3	+6.7	61	5	43	13	23	28	33	32	28	75	3.17	+.1	14	10.9	s.	39	sw.	5	1	6	24	8.4	6.9	T
Dayton	900	186	213	29.04	30.02		35.9	+6.4	62	4	43	13	23	29	35	32	29	77	3.49	+.3	12	11.7	sw.	46	sw.	5	2	5	24	8.5	9.0	T
Elkins	1,947	65	83	27.96	30.06	−.06	35.6	+5.2	64	9	44	5	28	27	39	31	26	74	4.89	+1.1	18	8.3	w.	33	nw.	25	3	7	21	8.1	18.0	1.0
Parkersburg	637	77	84	29.34	30.04	−.08	38.3	+5.8	64	4	46	13	23	30	36	34	30	76	2.71	−.9	16	7.6	sw.	30	w.	22	4	5	22	7.9	5.6	T
Pittsburgh [1]	1,273	39	54	28.63	30.00	−.11	33.2	+2.5	62	4	41	6	26	26	33	30	26	77	2.89	−.2	17	12.6	sw.	45	w.	22	1	7	23	8.3	15.1	1.0
Lower Lake Region							27.4	+2.9										80	2.69	+0.1									8.4		
Buffalo	768	243	280	29.14	30.06	−.07	26.3	+1.7	55	10	33	−1	26	20	35	23	20	82	2.90	−.4	23	18.5	w.	61	w.	22	0	3	28	9.1	29.4	11.8
Canton	448	10	61	29.51	30.01		16.4	+.1	51	10	26	−26	27	6	48	15	12	84	2.05	−.4	13	10.3	w.	32	w.	22	7	5	19	7.1	15.4	6.6
Ithaca	836	77	109	29.07	30.01		26.4	+2.1	54	10	34	−2	27	19	30	21	21	84	2.82	+.6	16	9.4	nw.	37	se.	5	1	3	27	8.7	27.5	16.0
Oswego	335	71	85	29.63	30.01	−.06	24.3	+.4	56	10	32	−9	26	17	35	23	17	74	3.21	+.3	21	11.4	s.	34	w.	22	1	4	26	9.2	33.3	17.4
Rochester	523	86	102	29.43	30.02	−.05	26.0	+1.4	56	10	33	0	25	19	34	23	20	80	3.39	+.5	19	10.4	w.	34	w.	22	1	7	23	8.6	34.4	17.0
Syracuse	596	65	79	29.33	29.99	−.08	25.6	+1.5	56	10	33	−7	26	18					2.74	−.3	22	8.2	w.	28	sw.	22	0	7	24	8.7	31.3	16.0
Erie	690	57	81	29.21	30.00	−.08	30.6	+3.8	60	9	37	8	26	24	31	27	24	80	2.71	−.1	19	10.6	w.	35	se.	5	1	5	25	8.8	11.7	4.8
Cleveland	762	267	318	29.14	29.99	−.10	32.5	+5.0	66	5	40	8	25	25	27	29	25	77	2.43	−.1	17	16.7	s.	55	w.	22	0	6	25	8.8	12.7	.1
Sandusky	629	5	67	29.29	30.00	−.09	31.3	+5.0	61	5	39	9	26	24	28				2.11	−.2	16	10.9	sw.	33	w.	22	0	8	23	8.5	13.4	2.4
Toledo	628	79	87	29.31	30.01	−.08	30.2	+4.4	60	5	37	7	25	24	27	28	24	78	2.53	+.4	18	10.9	w.	32	e.	30	3	8	20	7.7	16.4	5.8
Fort Wayne	857	69	84	29.06	30.01		31.4	+5.2	60	5	38	8	23	25	28	29	26	83	2.89	+.6	18	10.4	w.	34	ne.	30	4	8	19	7.5	13.9	5.5
Detroit [1]	626	5	78	29.29	29.99	−.09	27.8	+3.4	58	10	34	2	25	21	29	26	23	83	2.54	+.5	20	11.8	sw.	40	w.	22	3	5	23	8.4	21.1	9.9
Upper Lake Region							23.5	+5.6										82	2.24	+0.4									8.1		
Alpena	609	13	80	29.28	29.97	−.07	23.1	+4.0	49	10	30	−11	26	16	33	20	17	80	2.26	+.4	21	12.0	nw.	40	nw.	22	5	3	23	7.8	22.6	4.4
Escanaba	612	41	49	29.99	29.98	−.07	20.4	+5.0	41	10	28	−6	25	13	28	19	15	79	2.83	+1.3	15	10.8	s.	37	nw.	24	3	5	23	8.1	18.7	6.0
Grand Rapids	701	70	244	29.19	29.98	−.08	28.6	+4.1	57	9	34	6	25	23	22	26	23	81	2.48	+.1	18	12.6	sw.	52	sw.	9	1	5	25	8.7	21.5	8.4
Lansing	878	5	90	29.01	29.98		26.8	+4.4	56	9	33	3	25	20	29	23	23	88	2.34	+.5	16	10.0	s.	29	w.	22	4	5	22	7.9	18.7	11.1
Marquette	734	44	69	29.13	29.96	−.08	21.2	+4.9	43	10	28	−1	22	15	29	19	17	82	2.21	−.1	18	8.1	s.	32	nw.	22	1	8	22	8.5	14.6	8.8
Sault Sainte Marie [1]	724	5	33	29.14	29.97	−.06	16.0	+2.7	40	5	26	−25	25	6	40	14	12	88	2.89	+.9	21	8.5	se.	32	nw.	10	5	4	22	7.7	23.5	13.5
Chicago	673	7	131	29.24	29.98	−.12	31.6	+7.9	58	9	37	9	22	26	23	29	26	80	2.22	+.3	13	10.5	s.	33	ne.	30	3	3	25	8.4	24.7	12.3
Green Bay	617	109	141	29.27	29.97	−.09	23.1	+7.4	49	9	30	−6	25	17	28	21	18	80	1.83	+.3	12	11.2	s.	32	s.	9	4	4	23	8.0	4.7	3.3
Milwaukee	681	97	221	29.20	29.96	−.12	28.6	+8.0	54	9	35	2	25	23	26	27	23	79	1.60	−.2	16	12.5	w.	34	sw.	5	3	5	23	8.4	15.7	3.5
Duluth	1,133	5	47	28.67	29.95	−.14	15.2	+7.3	35	9	23	−21	22	8	36	15	13	87	1.75	+.8	11	11.6	nw.	46	nw.	21	4	5	22	7.7	13.2	9.4
North Dakota							13.2	+8.5										87	0.55	0.0									6.8		
Moorhead, Minn	940	50	58	28.92	29.99	−.15	11.3	+7.5	34	9	21	−23	16	2	37	11	10	92	.58	−.1	11	7.9	s.	26	nw.	21	4	4	23	8.3	5.7	5.7
Bismarck	1,677	8	57	28.09	29.95	−.18	19.0	+11.2	46	8	29	−10	16	9	37	15	14	80	.32	−.1	6	7.8	nw.	30	nw.	23	8	10	13	6.1	2.0	.8
Devils Lake	1,478	11	44	28.32	29.97	−.15	9.4	+7.6	36	8	19	−22	16	0	40	8	7	91	.45	.0	12	8.4	se.	27	nw.	21	5	7	19	7.0	5.6	5.5
Grand Forks	833	12	67				7.4	+3.9	29	9	18	−28	16	−3	42	7	4		.65	+.1	9	9.1	nw.				3	8	20		6.6	7.6
Williston	1,878	42	50	27.88	29.92	−.19	18.9	+12.5	43	8	29	−17	17	9	40	18	15	85	.77	+.2	8	7.0	se.	20	nw.	25	9	10	12	5.8	8.5	7.6
Upper Mississippi Valley							30.9	+9.2										80	2.60	+0.4									7.4		
Minneapolis—St. Paul, Minn. [1]	848	32	61	29.02	29.97	−.14	19.6	+6.9	45	9	28	−10	22	12	36	19	16	86	1.06	+.2	11	9.8	nw.	34	nw.	21	3	5	23	8.1	7.4	2.8
La Crosse	714	11	48	29.18	29.98	−.13	24.7	+8.6	51	9	32	−3	22	18	38	23	19	80	1.10	.0	13	5.9	s.	22	nw.	21	3	6	22	7.9	10.0	1.8
Madison	974	70	78	28.88	29.97	−.13	26.2	+9.5	53	9	32	1	22	20	28	24	22	86	1.95	+.6	14	9.0	s.	29	n.	30	2	5	24	8.4	7.0	2.0
Charles City	1,015	10	51	28.85	29.98	−.16	23.8	+10.1	50	9	32	−6	22	16	32	22	20	85	1.16	+.1	9	7.0	nw.	23	w.	22	3	10	18	7.3	8.5	.5
Davenport	606	66	161	29.31	29.99	−.13	31.3	+9.5	61	9	38	5	22	24	28	29	25	80	1.40	.0	10	10.1	nw.	34	nw.	21	3	12	16	7.6	6.8	T
Des Moines	861	5	99	29.04	29.97	−.17	30.8	+10.7	60	8	40	4	16	22	32			78	1.10	.0	9	9.9	nw.	31	nw.	24	6	11	14		5.6	.0
Dubuque	699	60	79	29.20	29.98	−.14	28.4	+9.3	58	9	35	1	22	22	32	26	23	81	.81	−.5	13	6.8	nw.	27	nw.	21	4	8	19	7.6	5.6	.1
Keokuk	614	64	78	29.32	29.99	−.15	35.2	+10.3	65	9	43	11	22	27	28	31	27	75	.92	−.6	12	8.6	sw.	27	nw.	22	5	9	17	7.1	3.7	.9
Cairo	358	87	93	29.66	30.05	−.11	43.2	+8.3	68	3	51	23	23	36	27	38	32	71	4.15	+.4	10	10.2	s.	29	sw.	5	6	5	20	7.0	2.1	.0
Peoria	609	11	45	29.32	30.00	−.12	32.2	+9.1	60	9	40	5	31	23	28	30	27	86	3.40	+1.6	13	7.3	s.	24	ne.	30	10	7	14	6.1	15.5	7.0
Springfield, Ill.	636	5	101	29.30	30.00	−.13	35.4	+8.9	62	8	42	13	19	29	28	33	29	79	2.89	+.8	12	12.4	s.	32	nw.	26	3	9	19	7.6	16.3	7.0
St. Louis	568	179	303	29.39	30.01	−.13	40.4	+9.3	70	3	47	19	22	34	28	35	30	70	4.08	+1.7	10	13.0	sw.	33	sw.	9	8	7	16	6.5	10.6	.6
Missouri Valley							34.6	+10.9										71	1.20	+0.1									5.2		
Columbia, Mo	784	6	66	29.15	30.00	−.13	39.4	+10.2	67	9	47	16	22	31	29				1.66	−.3	12	9.3	w.	27	nw.	22	3	14	14	6.8	7.9	1.2
Kansas City [1]	750	32	45				38.5	+10.5	67	2	48	12	16	29	34			69	1.28	+.1	9	10.4	sw.	34	sw.	9	7	8	16		6.1	.0
St. Joseph	957	11	49	28.92	29.98		36.8	+11.3	71	2	46	8	16	28	30	32	26	70	.93	−.4	9	9.4	nw.	30	nw.	21	10	9	12	5.7	5.0	.0
Springfield, Mo	1,324	5	78	28.59	30.02	−.12	40.8	+7.3	67	2	49	19	16	32	33	36	30	70	2.70	+.4	7	10.1	w.	27	w.	5	11	9	11	5.5	10.0	T
Topeka	987	65	87	28.91	29.98		38.5	+10.9	74	2	48	9	16	29	34	33	26	65	.70	−.2	9	9.9	w.	29	sw.	27	7	11	13	6.0	6.5	.0
Lincoln	1,189	11	81	28.67	29.97	−.18	34.8	+12.0	72	2	44	8	22	26	38	30	23	66	.59	.0	6	9.7	s.	31	nw.	21	8	9	14	6.1	7.9	.0
Omaha [1]	982	31	44	28.90	29.98	−.17	33.0	+11.1	65	2	42	4	22	24	33	29	25	76	.50	−.2	7	10.8	se.	38	nw.	21	8	7	16	6.4	4.4	.0
Valentine	2,598	47	54	27.17	29.96	−.16	30.6	+11.7	62	1	41	0	15	30	40	26	21	73	1.36	+.9	5	9.5	w.	30	nw.	14	5	15	11	6.0	3.7	T
Sioux City	1,138	64	106	28.71	29.96	−.19	29.5	+11.7	61	1	38	−4	18	21	38	26	22	73	1.00	+.3	8	9.4	nw.	30	nw.	21	4	12	15	6.9	6.8	T
Huron	1,307	59	74	28.53	29.97	−.19	23.6	+12.3	55	1	34	−9	18	14	39	21	18	79	1.33	+.8	9	8.7	se.	28	nw.	14	8	13	10	6.1	6.9	T
Northern Slope							29.3	+9.6										69	0.58	−0.2									6.8		
Havre	2,507	11	67	27.24	29.93	−.17	28.8	+15.9	48	7	38	−12	31	20	34	26	22	73	.30	−.4	5	10.1	sw.	29	sw.	23	3	13	15	6.9	3.0	1.8
Helena	4,124	85	111	25.72	30.00	−.15	31.6	+11.4	59	1	38	7	22	25	25	27	19	59	.20	−.7	8	8.5	sw.	29	sw.	25	3	5	21	7.6	4.5	.7
Missoula	3,238	80	91				33.8	+11.5	60	1	40	11	22	28	22				.59	−.4	13	5.9	w.	28	sw.	2	1	5	25	8.6	5.5	T
Kalispell	2,973	48	56	26.92	30.02	−.10	30.2	+9.8	53	1	36	7	22	24	23	29	26	82	1.27	−.3	15	4.5	w.	20	w.	3	1	3	27	8.5	18.8	3.9
Miles City	2,371	48	55	27.39	29.94	−.18	28.9	+14.4	50	27	39	0	31	19	31	26	21	73	.30	−.4	8	6.6	s.	29	nw.	23	3	14	14	6.7	3.8	2.9
Rapid City	3,259	50	58	26.49	29.92	−.18	32.4	+10.4	64	1	43	3	22	22	39	28	19	58	.38	−.1	5	8.5	nw.	34	nw.	23	7	16	8	6.0	3.9	3.2
Cheyenne [1]	6,144	5	39	23.82	29.99	−.06	28.2	+2.7	54	1	38	1	13	18	36	24	18	68	.71	+.3	7	14.9	nw.	44	nw.	19	7	9	15	6.5	5.1	T
Lander	5,352	60	68	24.55	30.03	−.09	25.2	+6.9	52	2	38	0	22	13	35	20	13	63	.28	−.3	4	4.7	sw.	55	sw.	1	10	12	8	5.2	3.0	1.7
Sheridan	3,790	10	47	25.99	29.98		28.6		65	2	41	−1	15	16	37	25	18	64	.40	−.4	8	5.7	nw.	33	nw.	13	7	13	11	6.1	4.6	1.0
Yellowstone Park	6,241	12	46				21.4	+3.8	39	1	29	2	22	14				74	1.21	+.4	16	8.8	sw.	30	sw.	1	8	5	18		19.2	6.9
North Platte	2,821	11	51	26.98	29.98	−.14	32.6	+9.7	62	1	44	5	15	22	35	27	22	72	.70	+.3	6	7.9	w.	32	nw.	9	10	6	15	6.0	4.1	T

[1] Observations taken at airport.

TABLE 2.—*Climatological data for Weather Bureau stations, January 1939*—Continued

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01 inch or more	Wind: Average hourly velocity	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles								0–10	In.	In.
Middle Slope								38.1	+7.6									62	1.31	+0.7										5.1		
Denver	5,292	106	113	24.63	29.99	−0.06	33.4	+3.6	64	1	43	8	15	24	31	27	18	56	0.74	+.3	6	8.1	s.	29	n.	14	12	9	10	5.3	9.6	0.0
Pueblo	4,690	79	86	23.21	29.97	−.08	34.4	+4.3	69	1	46	5	15	22	39	29	21	59	1.20	+.9	12	7.1	nw.	32	nw.	4	11	12	8	4.7	9.2	.0
Concordia	1,392	50	58	28.47	29.97	−.17	36.8	+10.4	69	2	46	11	22	27	35	31	24	66	.40	−.2	6	9.3	w.	30	nw.	4	12	9	10	4.7	4.5	.0
Dodge City	2,509	10	86	27.33	29.98	−.13	38.4	+9.4	70	2	50	15	15	26	41	31	23	58	.68	+.3	4	12.3	nw.	37	nw.	9	11	10	10	5.2	.8	.0
Wichita	1,358	85	93	28.53	30.00	−.13	40.5	+9.2	65	3	50	16	22	32	30	35	28	64	1.09	+.3	5	10.9	s.	30	s.	27	9	10	12	5.6	3.0	.0
Oklahoma City	1,214	10	47	28.71	30.02	−.09	45.0	+8.6	71	3	54	22	15	35	33	38	31	56	3.76	+2.6	7	10.6	s.	25	s.	16	13	8	10	5.2	3.1	.0
Southern Slope								47.0	+4.2									58	1.58	+0.9										4.6		
Abilene	1,738	10	56	28.20	30.04	−.05	49.0	+4.8	74	3	60	29	15	38	38	41	32	59	1.60	+.6	6	10.7	s.	31	s.	10	12	5	14	5.4	T	.0
Amarillo	3,676	10	49	26.20	29.98	−.08	41.9	+6.6	72	2	52	23	15	32	38	34	27	56	2.51	+2.0	8	9.8	sw.	28	nw.	4	13	8	10	4.8	6.9	.0
Del Rio	900	63	71	29.02	30.02	−.04	54.4	+2.1	76	7	64	34	18	45	35	48	41	66	1.46	+.9	7	8.6	se.	31	nw.	4	14	6	11	4.6	.0	.0
Roswell	3,566	75	85	26.38	30.01	−.03	42.7	+3.5	68	1	56	21	1	29	47	35	25	52	.77	+.2	7	8.7	nw.	40	nw.	4	18	10	3	3.4	.6	.0
Southern Plateau								40.7	+1.0									56	0.98	+0.1										3.9		
El Paso	3,778	82	101	26.19	30.03	+.02	45.8	+.8	74	6	58	27	2	34	38	37	24	45	.65	+.2	3	8.7	w.	31	sw.	31	10	13	2	3.5	T	.0
Albuquerque [1]	5,314	5	39	25.04	30.06	.....	34.4	+.3	55	1	46	15	5	25	35	28	21	63	.70	+.3	4	8.0	n.	41	w.	31	16	4	11	4.5	1.0	T
Santa Fe	7,013	28	53	23.17	30.06	+.02	28.8	.0	52	2	38	7	15	20	28	24	17	62	1.93	+1.3	11	6.5	n.	22	e.	7	16	4	11	4.4	18.1	3.0
Flagstaff	6,907	10	59	23.28	29.99	−.02	27.6	+.9	51	19	40	0	29	15	45	25	...	70	1.26	−1.6	8	8.7	sw.	28	nw.	28	9	12	10	.....	16.0	3.0
Phoenix	1,107	39	51	28.86	30.03	.00	52.4	+1.2	72	1	65	35	18	40	36	43	31	49	.18	−.6	2	5.8	e.	28	nw.	28	16	9	6	4.1	.0	.0
Yuma	141	9	54	29.89	30.04	−.01	55.2	+.8	73	26	66	38	14	44	31	46	34	50	.91	+.5	4	6.5	n.	24	nw.	31	18	9	4	3.0	.0	.0
Independence	3,957	5	26	.....	.....	.....	40.9	+2.7	64	27	32	24	1	30	32	33	20	...	1.24	+.3	3	.....	nw.	...	.....	...	17	5	9	.....	.0	.0
Middle Plateau								29.8	+2.1									74	0.99	0.0										6.1		
Reno	4,527	61	76	25.51	30.11	−.02	36.2	+4.6	65	1	46	18	16	26	38	31	24	63	1.32	−.2	5	6.2	sw.	29	w.	30	11	10	10	5.1	2.0	T
Tonopah	6,090	12	20	.....	.....	.....	31.5	.....	47	19	38	15	31	25	19	28	24	74	.30	.....	4	.....	nw.	...	.....	...	.....	.....	.....	.....	3.3	T
Winnemucca	4,344	18	56	25.67	30.15	−.01	30.4	+1.8	53	2	42	9	31	19	35	27	22	72	.94	−.1	9	7.3	ne	36	s.	5	7	5	19	7.0	6.8	1.8
Modena	5,473	10	43	24.61	30.09	−.01	28.4	−1.3	51	1	37	2	24	14	35	24	20	76	.74	−.1	7	8.0	w.	30	sw.	30	10	9	12	5.7	10.2	1.2
Salt Lake City [1]	4,227	32	46	25.77	30.13	−.02	30.5	.....	47	2	38	10	31	23	24	28	25	80	1.23	.....	12	7.8	se.	43	nw.	3	5	13	13	6.7	11.8	6.0
Grand Junction	4,602	60	68	25.41	30.08	+.02	27.4	+3.4	44	7	37	9	4	18	27	24	20	76	.95	+.4	6	4.4	n.	21	w.	31	10	7	14	5.8	6.6	2.4
Northern Plateau								35.2	+6.8									77	0.99	−0.7										8.1		
Baker	3,471	36	54	26.49	30.14	−.02	30.0	+5.1	48	2	38	4	31	22	28	28	23	81	.52	−.9	5	5.8	s.	22	s.	2	3	5	23	8.3	8.4	3.2
Boise	2,739	79	87	27.25	30.18	−.01	34.0	+4.2	61	1	41	15	31	27	27	31	27	76	1.19	−.5	9	5.5	se.	26	se.	4	5	5	21	7.6	5.0	T
Pocatello [1]	4,466	5	31	25.49	30.15	−.05	27.8	.....	51	2	35	4	24	20	30	27	23	81	.94	.....	11	10.2	sw.	31	w.	3	3	5	23	8.2	8.6	1.0
Spokane	1,929	101	110	27.98	30.07	−.05	34.6	+7.1	56	1	39	20	23	30	15	33	30	82	1.55	−.6	16	6.4	s.	21	s.	3	1	6	24	8.5	6.0	T
Walla Walla	991	37	65	29.00	30.09	−.06	41.1	+8.4	67	1	48	25	22	34	22	37	32	69	1.30	−.7	12	6.0	s.	28	w.	3	4	7	20	7.8	.7	.0
Yakima	1,076	58	67	28.90	30.07	.....	36.4	+9.0	56	17	44	22	23	29	27	33	28	72	.39	−.9	6	4.7	nw.	22	w.	17	3	7	21	7.9	1.9	.0
North Pacific Coast Region								43.0	+3.0									84	5.94	−0.7										8.9		
North Head	211	11	56	29.83	30.06	+.01	44.1	+2.0	52	1	48	34	30	41	16	43	42	92	[1]0.05	+1.3	20	17.2	s.	67	s.	1	0	7	24	8.8	.0	.0
Seattle	125	90	321	29.91	30.04	−.01	44.7	+5.2	56	17	48	34	21	41	15	42	39	82	5.11	+.2	25	11.3	s.	41	sw.	18	0	3	28	8.8	.0	.0
Tacoma	263	172	201	29.85	30.06	+.02	43.4	+4.6	60	1	47	30	25	39	16	...	...	...	5.25	−.9	25	9.6	s.	36	s.	2	0	3	28	9.1	T	.0
Tatoosh Island	86	9	55	29.88	29.98	.00	44.0	+2.8	52	1	46	34	29	42	8	43	40	85	11.32	−.5	28	17.6	e.	57	e.	25	0	4	27	8.9	.7	.0
Medford [1]	1,329	29	58	28.73	30.18	.....	38.2	+.3	65	1	44	23	24	32	25	36	34	86	1.92	−.9	13	.....	n.	...	.....	...	1	2	28	8.9	2.4	.0
Portland, Oreg	154	68	106	29.94	30.11	+.03	43.8	+4.4	58	1	48	33	6	40	16	42	39	82	4.69	−1.9	20	6.7	se.	21	w.	2	0	6	25	8.8	T	.0
Roseburg	510	45	76	29.58	30.14	+.04	42.6	+1.4	64	1	49	28	24	36	23	40	37	79	3.26	−2.0	16	3.8	sw.	25	sw.	2	1	3	27	8.9	T	.0
Middle Pacific Coast Region								48.2	+1.3									73	3.34	−2.2										6.7		
Eureka	60	72	88	30.08	30.15	+.05	46.5	−.4	63	25	53	33	31	40	27	44	41	82	4.49	−2.6	15	6.8	se.	27	s.	1	4	9	18	7.0	T	.0
Redding [1]	722	20	34	.....	.....	.....	48.0	+2.7	72	25	56	30	31	40	31	42	32	67	3.88	−3.0	8	8.1	nw.	28	s.	29	5	7	19	7.2	.0	.0
Sacramento	66	92	115	30.05	30.12	.00	46.5	+.7	64	21	55	31	24	38	27	44	40	77	1.91	−1.8	10	6.7	se.	26	nw.	8	6	12	13	6.4	.0	.0
San Francisco	155	112	132	29.94	30.13	+.02	52.0	+2.1	66	14	58	40	31	46	20	47	43	75	3.07	−1.5	7	6.3	w.	26	sw.	4	7	9	15	6.2	.0	.0
South Pacific Coast Region								53.2	+1.5									69	2.44	+0.2										5.7		
Fresno	327	97	105	29.76	30.13	+.03	47.0	+.8	64	14	56	33	9	39	27	45	41	80	1.99	+.3	9	4.9	e.	21	se.	5	4	9	18	7.3	.0	.0
Los Angeles	338	159	191	29.70	30.06	−.02	57.0	+2.4	79	24	65	41	15	49	27	49	40	58	2.96	−.1	4	6.1	ne.	21	nw.	28	16	5	10	4.3	.0	.0
San Diego	87	62	70	29.96	30.06	−.01	55.6	+1.3	73	24	64	43	29	48	26	50	44	68	2.38	+.3	11	6.2	e.	30	w.	31	9	11	11	5.4	.0	.0
West Indies																																
San Juan, P. R.	82	9	54	29.97	30.06	.....	74.4	−.6	84	14	79	66	21	70	15	...	...	...	3.11	−1.0	18	12.6	e.	31	e.	29	6	23	2	4.7	.0	.0
Panama Canal																																
Balboa Heights	118	6	92	.....	.....	.....	...	...	...	...	...	...	...	...	...	...	...	...	.....	.....	...	.....	...	...	...	...	...	...	...	.....	.....	.....
Cristobal	36	6	97	.....	.....	.....	...	...	...	...	...	...	...	...	...	...	...	...	.....	.....	...	.....	...	...	...	...	...	...	...	.....	.....	.....
Alaska																																
Fairbanks	454	11	87	.....	29.75	.....	−10.6	+1.5	18	24	−3	−44	19	−19	46	...	...	88	.68	−.1	12	3.1	s.	21	s.	24	5	9	17	.....	13.1	23.1
Juneau	80	96	116	[2]29.57	[2]29.66	.....	33.6	+6.2	43	12	36	14	31	31	9	32	29	81	10.17	+3.2	23	8.2	s.	24	s.	23	1	0	30	9.5	17.8	.3
Nome	22	5	32	.....	.....	.....	...	...	...	...	...	...	...	...	...	...	...	...	.....	.....	...	.....	...	...	...	...	...	...	...	.....	.....	.....
Hawaiian Islands																																
Honolulu	38	86	100	29.98	30.02	.....	72.7	+1.8	80	31	77	65	3	68	13	67	64	76	2.77	−1.0	19	10.2	e.	36	e.	10	5	19	7	5.7	.0	.0

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Panama Canal																																
Balboa Heights	118	6	92	.....	[2]29.82	+0.01	78.9	−1.0	90	30	86	69	18	72	19	...	...	[3]86	7.91	+3.3	20	5.4	nw.	27	n.	19	0	25	6	6.6	0.0	0.0
Cristobal	36	6	97	.....	[2]29.84	.00	79.6	−1.9	86	24	84	72	6	76	12	74	73	[3]82	29.29	+17.8	25	10.5	n.	26	nw.	16	4	12	15	6.8	.0	.0

[1] Observations taken at airport. [2] Pressure not reduced to a mean of 24 hours. [3] Observations taken hourly.

TABLE 3.—*Data furnished by the Canadian Meteorological Service, January 1939*

Stations	Altitude above mean sea level, Jan. 1, 1919	Pressure			Temperature of the air						Precipitation		
		Station reduced to mean of 24 hours	Sea level reduced to mean of 24 hours	Departure from normal	Mean max.+ mean min.÷2	Departure from normal	Mean maximum	Mean minimum	Highest	Lowest	Total	Departure from normal	Total snowfall
	Feet	*In.*	*In.*	*In.*	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*	*In.*	*In.*	*In.*
Cape Race, Newfoundland	99												
Sydney, Cape Breton Island	48	29.66	29.80	−0.14	24.2	+2.5	30.8	17.5	44	6	3.72	−1.37	8.5
Halifax, Nova Scotia	88	29.57	29.85	−.13	23.3	+.3	29.2	17.4	43	6	4.31	−1.23	11.7
Yarmouth, Nova Scotia	65	29.77	29.88	−.12	26.2	−.6	32.6	19.9	45	6	4.86	−.02	26.6
Charlottetown, Prince Edward Island	38	29.74	29.83	−.13	19.0	+1.8	25.4	12.6	40	−3	2.51	−1.63	18.2
Chatham, New Brunswick	28	29.33	29.85	−.13	12.9	+.2	23.1	2.7	40	−15	1.45	−1.98	13.7
Father Point, Quebec	20	29.88	29.90	−.08	11.8	+2.8	18.7	4.8	41	−9	1.56	−.94	14.9
Quebec, Quebec	296												
Doucet, Quebec	1,236												
Montreal, Quebec	187												
Ottawa, Ontario	236	29.74	30.01	−.05	12.2	+.8	22.2	2.2	44	−27	2.76	−.20	23.8
Kingston, Ontario	285	29.68	30.01	−.06	18.4	+.2	25.7	11.2	45	−21	2.54	−.29	23.0
Toronto, Ontario	379	29.59	30.02	−.06	23.7	+1.0	30.4	17.0	52	−9	2.25	−.47	19.5
Cochrane, Ontario	930	29.90	29.99	−.09	.5	+.3	11.6	−10.6	40	−40	3.21	+1.71	25.8
White River, Ontario	1,244	28.56	29.99	−.03	2.8	+2.9	19.0	−13.4	38	−47	3.11	+1.47	17.9
London, Ontario	808	29.09	30.00		22.7	+.3	30.2	15.1	53	−6	2.45	−1.49	22.3
Southampton, Ontario	656												
Parry Sound, Ontario	688	29.27	29.79	−.25	16.2	+1.5	25.1	7.3	45	−27	5.00	+.98	46.8
Port Arthur, Ontario	644	29.24	29.99	−.08	11.1	+4.5	19.8	2.4	34	−30	1.88	+.90	16.5
Winnipeg, Manitoba	760	29.12	30.00	−.17	4.4	+7.0	13.6	−4.7	27	−32	.79	−.08	7.9
Minnedosa, Manitoba	1,690	28.07	29.99	−.13	6.0	+8.4	15.3	−3.3	33	−30	.43	−.38	4.3
Le Pas, Manitoba	860	28.97	30.01	−.14	−4.6	+2.7	6.8	−16.1	25	−40	1.81	+.64	11.8
Qu'Appelle, Saskatchewan	2,115	27.56	29.94	−.20	9.8	+9.0	18.0	1.7	38	−20	.79	+.08	7.9
Moose Jaw, Saskatchewan	1,759	27.85	29.92	−.21	14.4	+10.4	22.4	6.3	41	−16	.85	+.21	8.5
Swift Current, Saskatchewan	2,392	26.98	29.91	−.22	17.4	+10.5	26.0	8.7	41	−10	.64	−.04	6.4
Medicine Hat, Alberta	2,365	27.34	29.93	−.19	21.4	+8.8	31.8	11.0	42	−12	1.39	+.78	13.8
Calgary, Alberta	3,540	26.15	29.93	−.13	24.6	+13.3	34.8	14.5	49	−14	.31	−.18	3.1
Banff, Alberta	4,521												
Prince Albert, Saskatchewan	1,450	28.34	29.98	−.14	6.3	+10.4	14.1	−1.5	33	−26	.78	+.03	7.8
Battleford, Saskatchewan	1,592												
Edmonton, Alberta	2,150	27.53	29.92	−.14	16.2	+10.0	24.1	8.2	43	−20	.64	−.21	6.4
Kamloops, British Columbia	1,262												
Victoria, British Columbia	230	29.75	30.00	−.05	42.9	+4.3	46.0	39.8	51	33	4.65	+.28	.0
Barkerville, British Columbia	4,180												
Estevan Point, British Columbia	20												
Prince Rupert, British Columbia	170												
St. George's, Bermuda	158		30.09	−.04	68.3	+.5	68.1	58.6	73	50	1.70	−2.82	.0
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Cape Race, Newfoundland	99				31.8	+1.6	36.9	26.6	48	−13	7.86	+2.80	12.2
Banff, Alberta	4,251	25.26	30.03	−.05	17.0	+.3	25.4	8.5	47	−25	1.12	−.08	8.0

TABLE 4.—*Severe local storms, January 1939*

[Compiled by Mary O. Souder from reports submitted by Weather Bureau officials]

[The table herewith contains such data as has been received concerning severe local storms that occurred during the month. A revised list of tornadoes will appear in the United States Meteorological Yearbook]

Place	Date	Time	Width of path, yards	Loss of life	Value of property destroyed	Character of storm	Remarks
West Coast, Washington-California.[1]	1-6					Gales	Bridges smashed. In Oregon 800 feet of the Southern Pacific secondary tracks ripped from roadbeds, the steel and ties being deposited on the highway 60 miles away. Much property loss in beach communities along the coast; several lives lost.
Walla Walla, Wash	3	Midnight-1 a. m.				Thunderstorm and hail.	A grain warehouse unroofed; trees down and much hay blown from stacks in the fields.
Montgomery, La	3	8:10 p. m.	150	2	$10,000	Tornado	Storm passed through the center of town wrecking several homes, damaging others and uprooting trees. 2 persons killed when their home was demolished, 2 others injured.
Abbott, Miss	4	9:30 p. m.			1,000	Thundersquall	Property damaged; 2 persons injured.
Tennessee, Giles, and Overton Counties and vicinities.	4	P. m.			10,000	Wind	Several small churches in southeastern portion of Giles County demolished or damaged; several houses in the vicinity of Livingston, Overton County, damaged; minor damage in other communities.
Silerton, Tenn., vicinity of	4		100-300	4	40,000	Tornado	More than 20 persons injured; property damaged; path about 40 miles long.
New Mexico, north-central portion.	7-8			3		Snow	Roads blocked resulting in a large number of motorists being stranded on highways for several hours. In a small region west of Sapello, 100 persons were isolated.
Odessa, Tex	8	2 a. m.			5,000	Hail	Property damaged.
Lamesa, Tex	8	3 a. m.	50	0	1,500	Tornado	Property damaged; no details.
Cisco, Tex	8	Noon	75	0	2,500	do	2 persons injured; property damaged.
Dallas, Tex., and vicinity	8	3:50-6 p. m.		2	100,000	Wind, electrical	Wind of 60 miles an hour recorded at 4:31 p. m. Considerable damage to property in scattered areas. Houses unroofed; trees and many signs blown down. 1 person killed by a live wire, another passed away due to scare and heart attack.
Havre, Mont., and vicinity	11					Glaze	Streets, walks and highways icy making it dangerous for pedestrian and motor travel.
Raceland, La., vicinity of	12	P. m.			3,000	Wind	Church demolished; several houses damaged; 1 person injured.
Buffalo, N. Y., and vicinity	13	do		1		Snow	7 inches of snow recorded. Poor visibility caused the death of 1 person who was struck by a train and the injury of several in motor accidents. Airplane traffic in and out of Buffalo canceled during the storm.
Trenton, N. J	13					Snow	By midnight 6.5 inches of snow had fallen. Driving hazardous, traffic almost at standstill during late afternoon and early evening.
Indiana, northern portion[1]	15			2		Snow and ice	20 persons injured in motor accidents.
Minnesota, northern counties	21					Wind	Strong northwest winds caused snow to drift, blocking many side roads.
Oswego, N. Y., and vicinity[1]	21-23			1		Snow, sleet and ice	Driving and walking hazardous; signs torn from buildings or tipped over. Zero visibility responsible for several accidents.
Oklahoma City, Okla	22-23	10:24 p. m. 22d-5:40 a. m. 23d.				Glaze	All objects coated with ice ¼ inch thick.
Pulaski, N. Y.[1]	24-25					Snow and wind	Traffic moved slowly because of low visibility; many cars stalled; schools closed.
Bunkie and Mansura, La	29	11 a. m.			1,000	Wind	Many houses and barns damaged; cattle killed.
Kilbourne, La., vicinity of	29	11:30 a. m.	150	1	10,000	do	House demolished, killing 1 person and injuring 3.
Toledo, Ohio, and vicinity[1]	29-30	P. m.		3		Sleet, snow and ice	Huge drifts; streets impassable; short circuits in power linesc aused delay in electric service and business; train service interrupted; property damaged; accidents reported.
St. Landry, La., vicinity of	29	Noon				do	Barns and outbuildings damaged; much timber uprooted; mule killed.
Gretna, La., vicinity of	29					do	Roofs of several buildings damaged; 4 smokestacks of pumping station blown over; garage overturned; 2 persons injured.
Chicago, Ill	30			1		Heavy snow and wind.	14.9 inches of snow, the greatest 24-hour snowfall ever recorded, during this storm. All surface traffic hampered by drifts 3 to 4 feet deep and low visibility. Many automobiles stalled and abandoned. Many streets and highway blocked. 46 persons injured in traffic accidents.
Michigan, southern portion	30					Wind and snow	Worst snowstorm of the season, drifts being from 2 to 7 feet deep. In Detroit motor traffic was disrupted for several days.
Greenville, S. C	30	1:40 a. m.			1,200	Straight-line wind	85-foot radio tower of Eastern Air Lines blown down; trees uprooted.
Buffalo, N. Y., and vicinities	30-31			2	35,000	Snow	12 inches of snow recorded at 7:30 a. m., of the 31st. Many parked cars snowed in. 15 street cars derailed. Airplane traffic stopped. Schools in Buffalo and surrounding towns closed in the afternoon of the 30th and on the 31st. 700 men and 60 plows mobilized in Buffalo to fight the storm. Traffic throughout western New York almost at standstill. Main highways closed, many motorists seeking shelter overnight in nearby hotels. Amount estimated cost of removing snow in Buffalo alone.

[1] From press reports.

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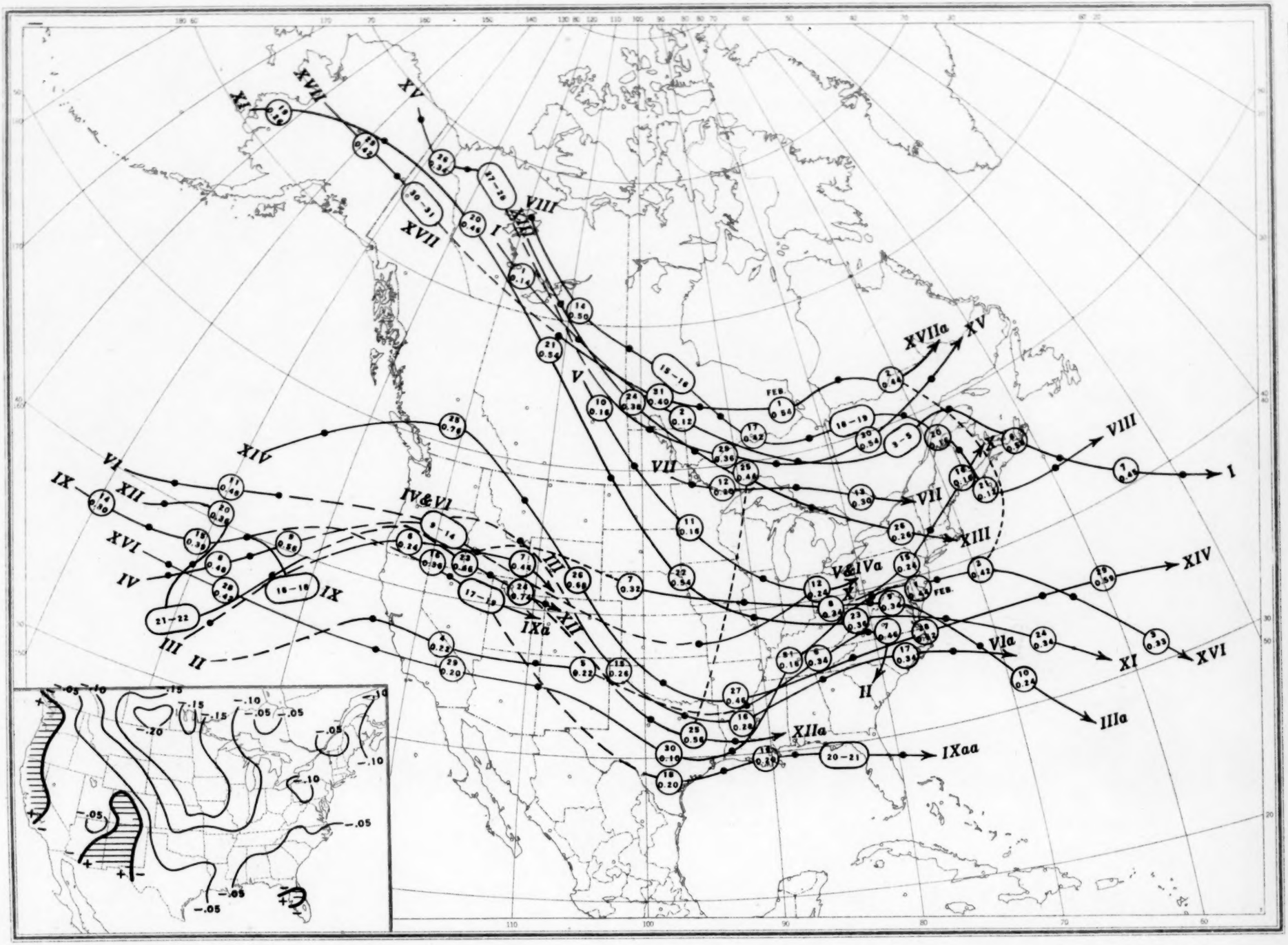
Chart I. Departure (°F.) of the Mean Temperature from the Normal, and Wind Roses for Selected Stations, January 1939

Chart I. Departure (°F.) of the Mean Temperature from the Normal, and Wind Roses for Selected Stations, January 1939

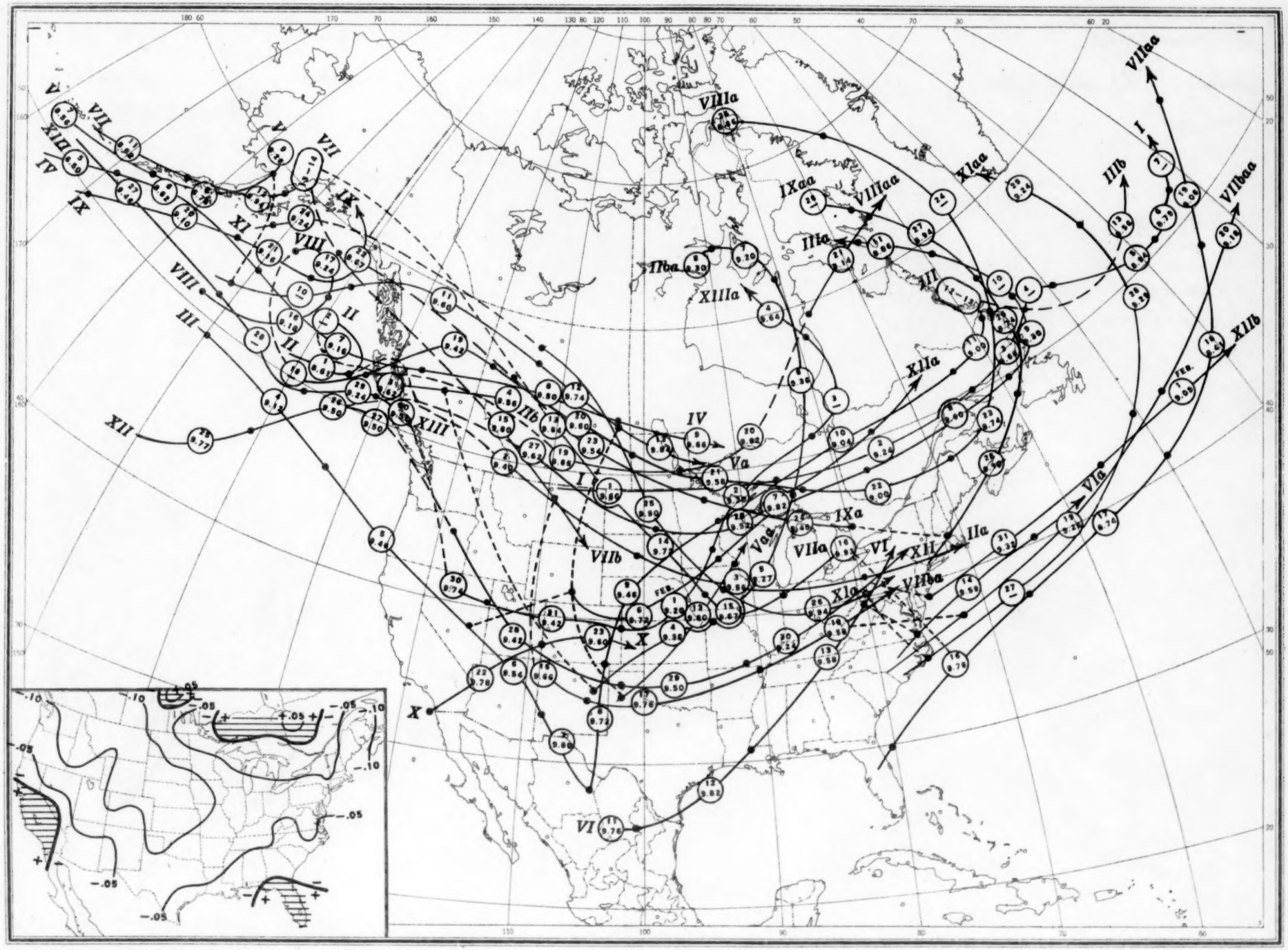
Chart II. Tracks of Centers of Anticyclones, January 1939. (Inset) Departure of Monthly Mean Pressure from Normal



Circle indicates position of anticyclone at 7:30 a. m. (75th meridian time), with barometric reading. Dot indicates position of anticyclone at 7:30 p. m. (75th meridian time).

Chart III. Tracks of Centers of Cyclones, January 1939. (Inset) Change in Mean Pressure from Preceding Month

Chart III. Tracks of Centers of Cyclones, January 1939. (Inset) Change in Mean Pressure from Preceding Month



Circle indicates position of cyclone at 7:30 a. m. (75th meridian time), with barometric reading. Dot indicates position of cyclone at 7:30 p. m. (75th meridian time).

Chart IV. Percentage of Clear Sky Between Sunrise and Sunset, January 1939

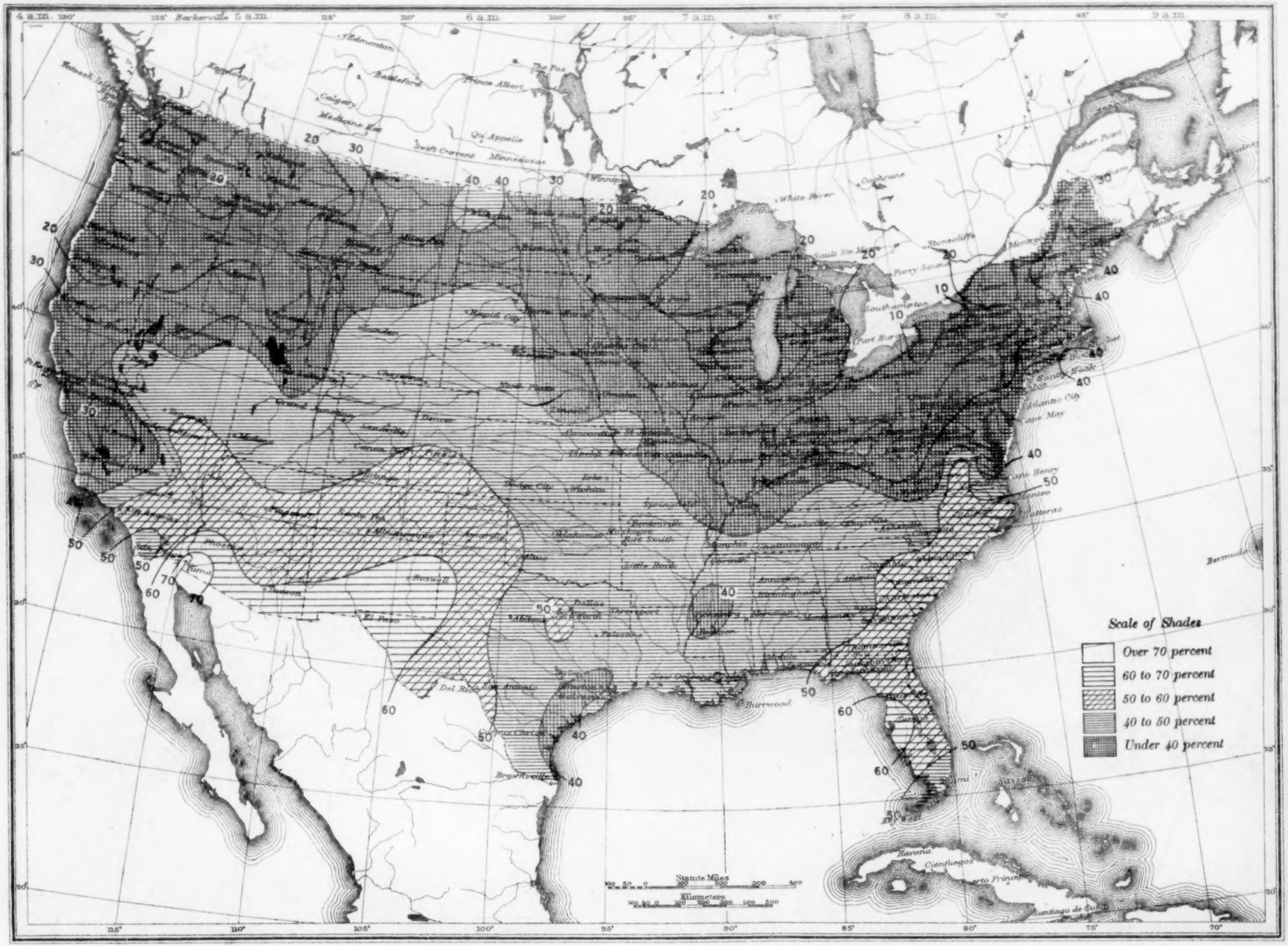


Chart V. Total Precipitation, Inches, January 1939. (Inset) Departure of Precipitation from Normal

Chart V. Total Precipitation, Inches, January 1939. (Inset) Departure of Precipitation from Normal

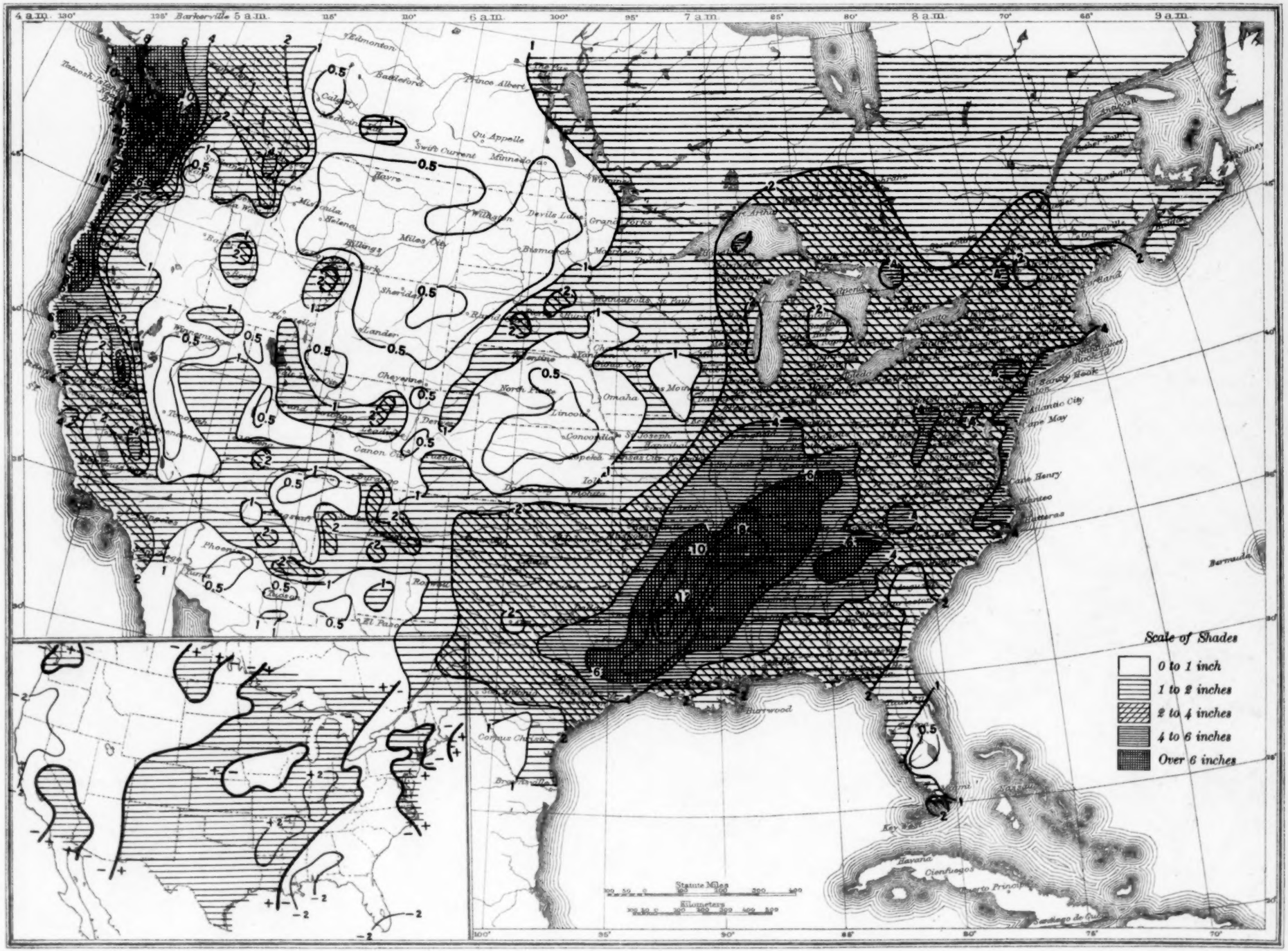


Chart VI. Isobars at Sea Level and Isotherms at Surface; Prevailing Winds, January 1939

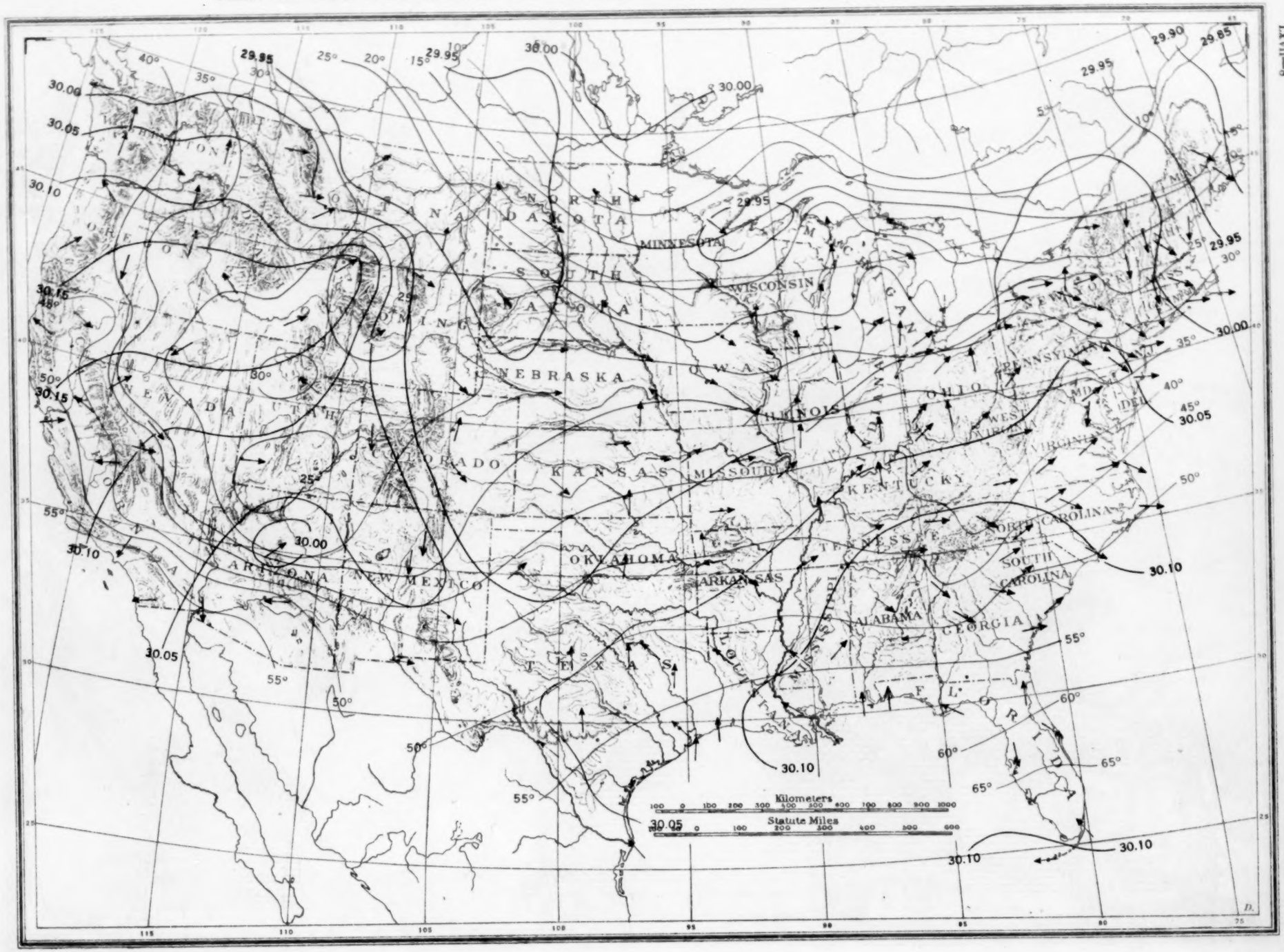


Chart VII. Total Snowfall, Inches, January 1939. (Inset) Depth of Snow on the Ground at 7:30 p.m., Monday, Jan. 30, 1939

Chart VII. Total Snowfall, Inches, January 1939. (Inset) Depth of Snow on the Ground at 7:30 p.m., Monday, Jan. 30, 1939

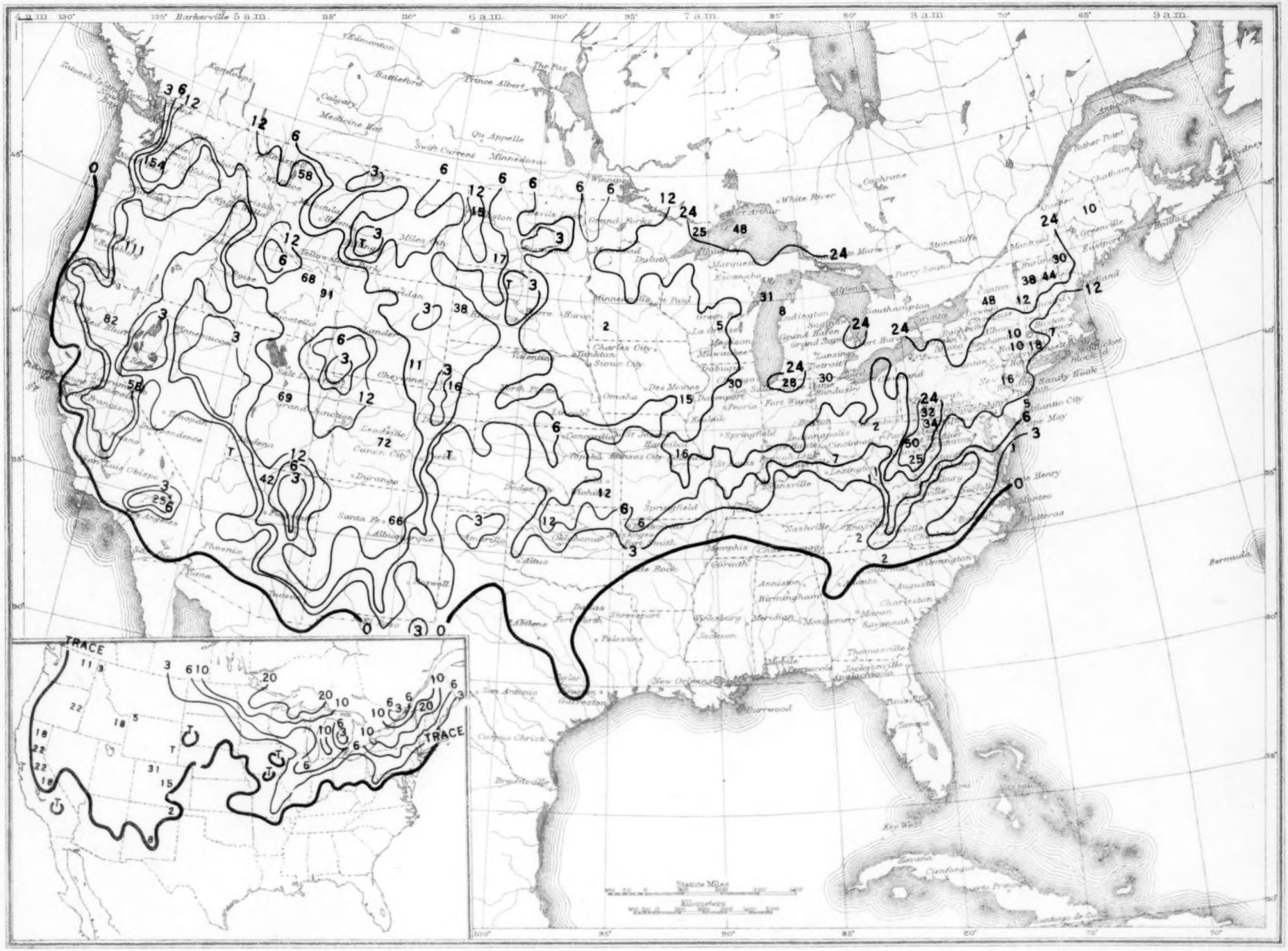


Chart VIII. Isobars (mb) for 1,524 Meters (5,000 ft.) and Isotherms (°C.) and Resultant Winds for 1,500 Meters (m. s. l.) January 1939

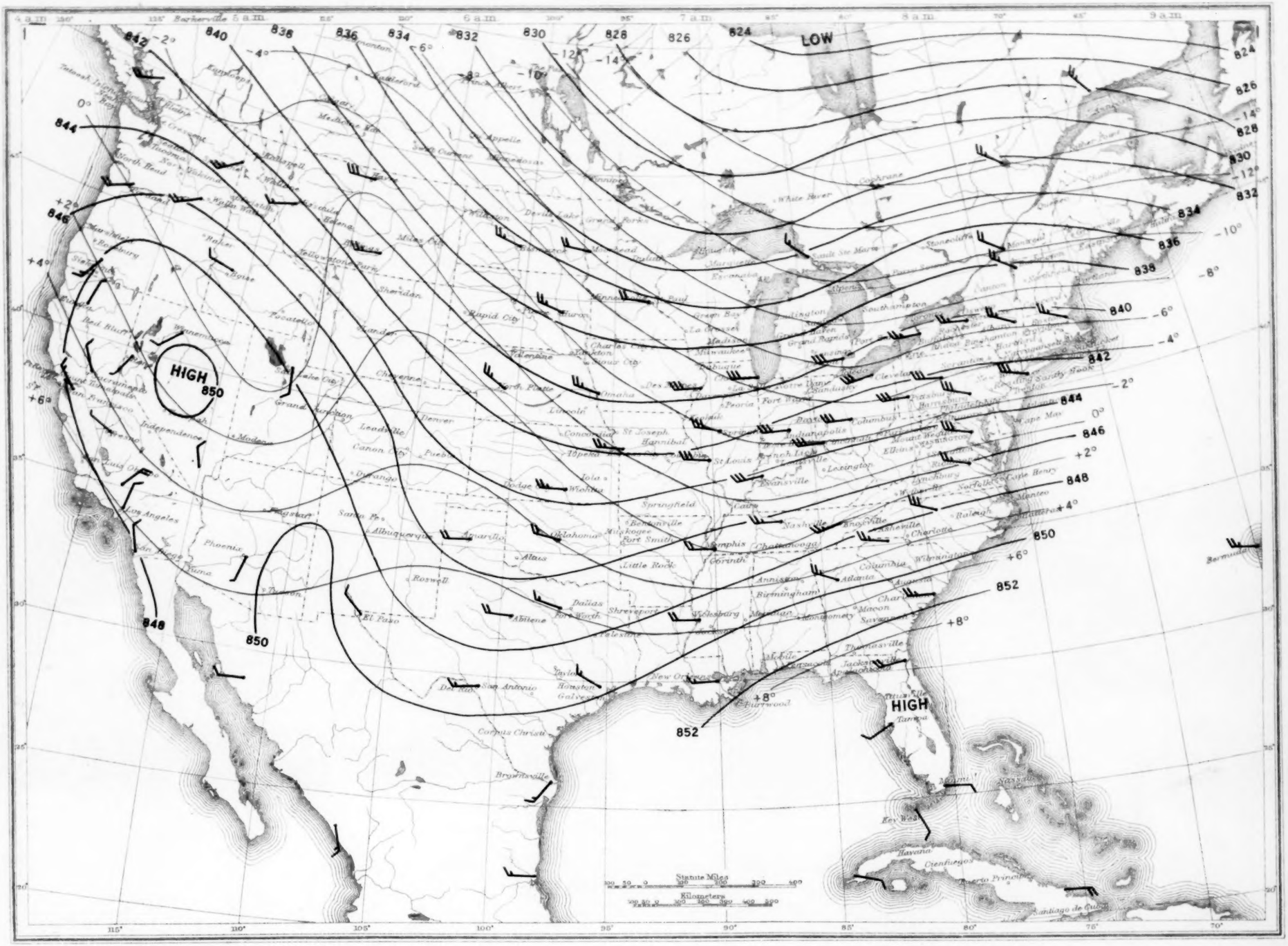


Chart IX. Isobars (mb) Isotherms (°C.) and Resultant Winds for 3,000 Meters (m. s. l.) January 1939

Chart IX. Isobars (mb) Isotherms (°C.) and Resultant Winds for 3,000 Meters (m. s. l.) January 1939

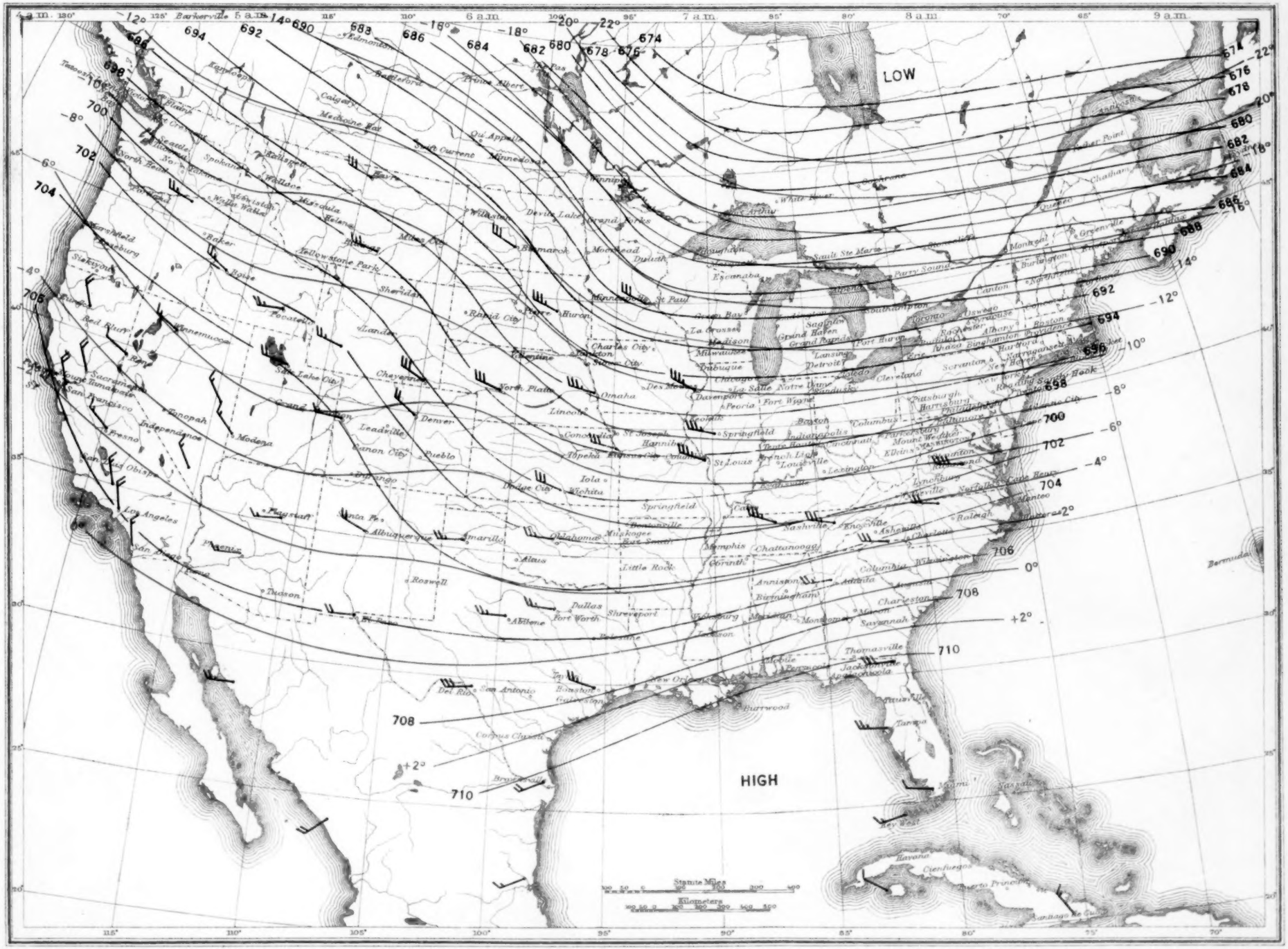


Chart X. Isobars (mb) Isotherms (°C.) and Resultant Winds for 4,000 Meters (m. s. l.) January 1939

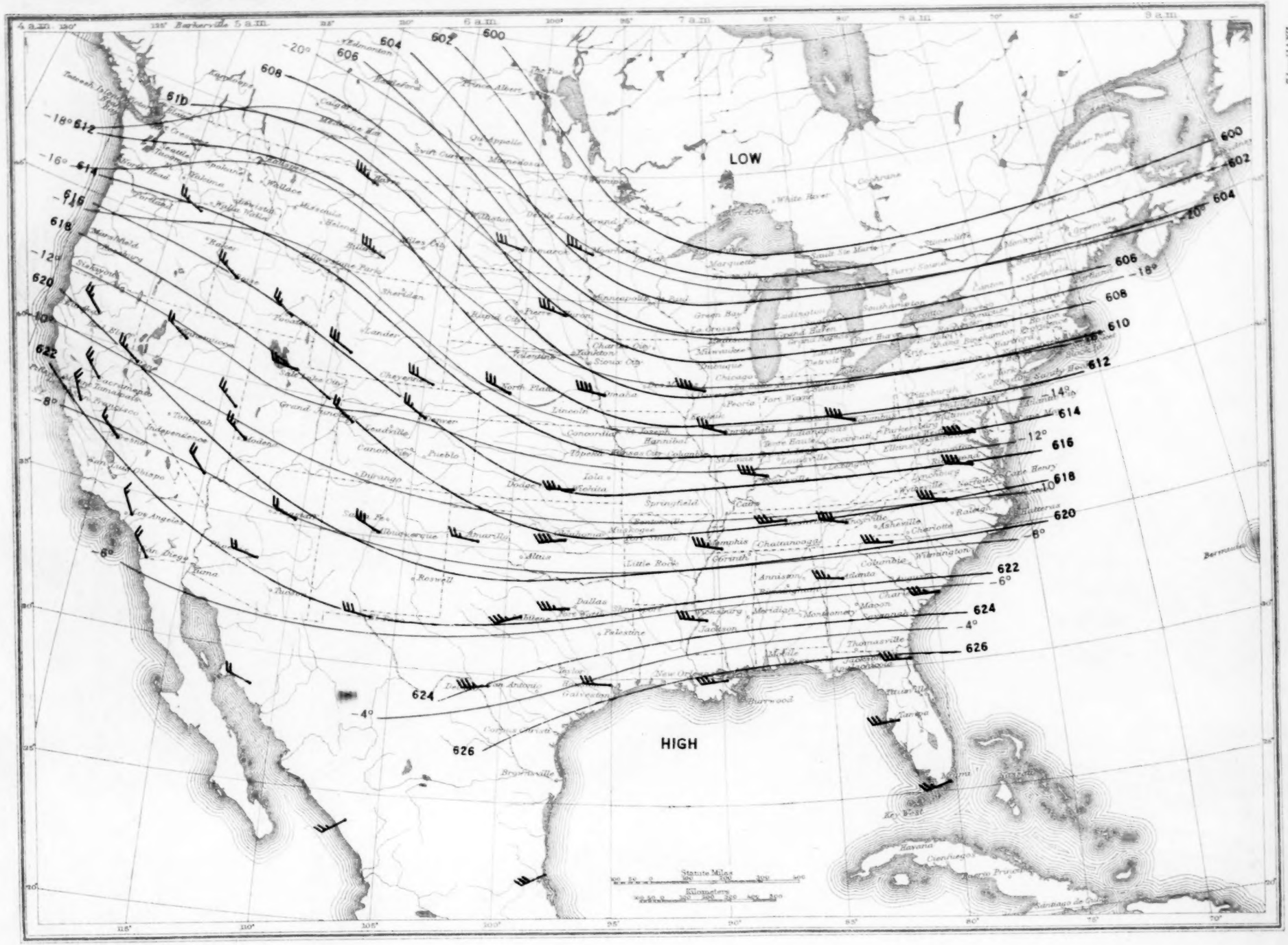


Chart XI. Isobars (mb) Isotherms (°C.) and Resultant Winds for 5,000 Meters (m. s. l.) January 1939

Chart XI. Isobars (mb) Isotherms (°C.) and Resultant Winds for 5,000 Meters (m. s. l.) January 1939

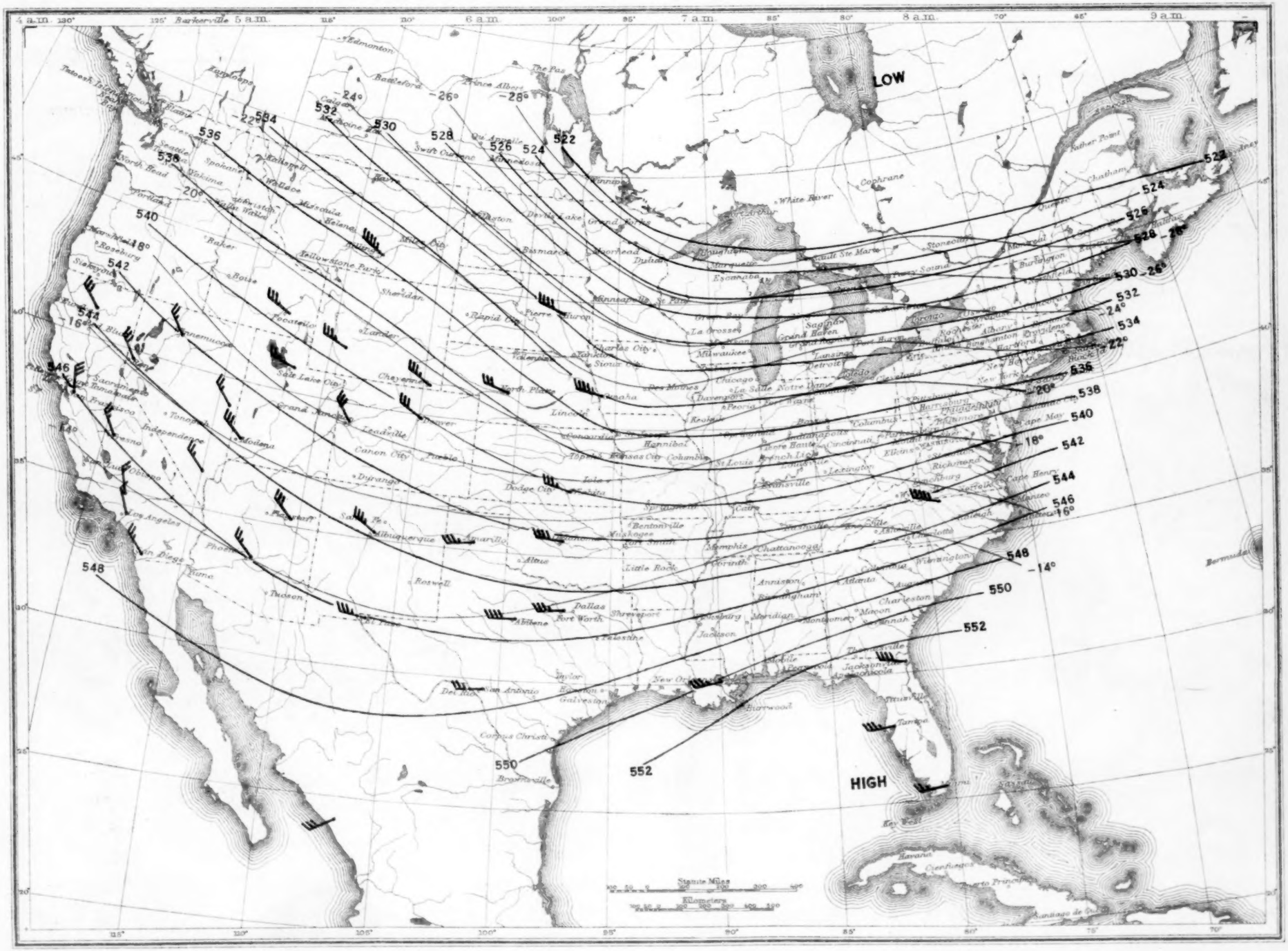


Chart XII. Mean Isentropic Chart, January 1939 (Potential Temperature 295° A.)

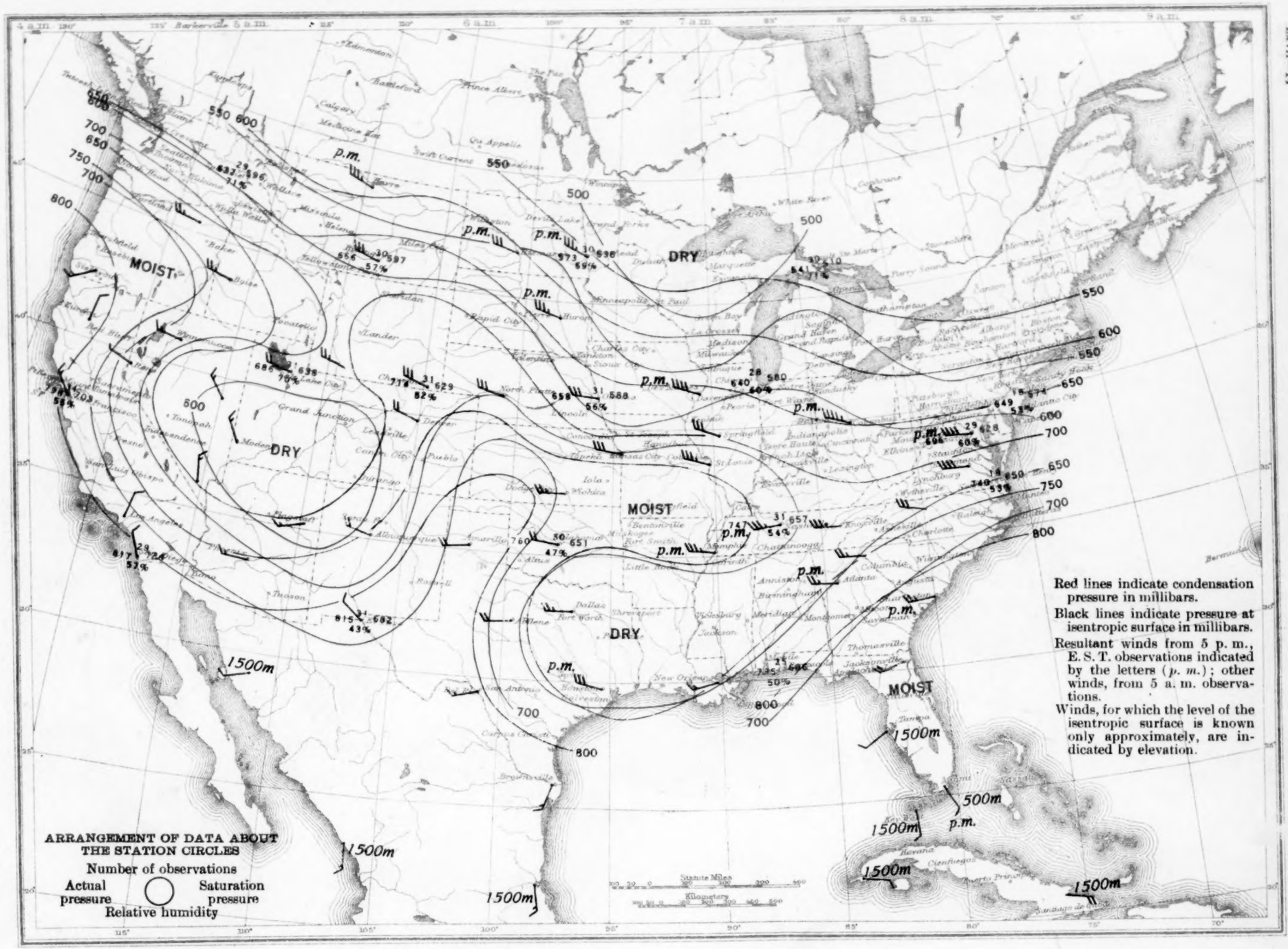
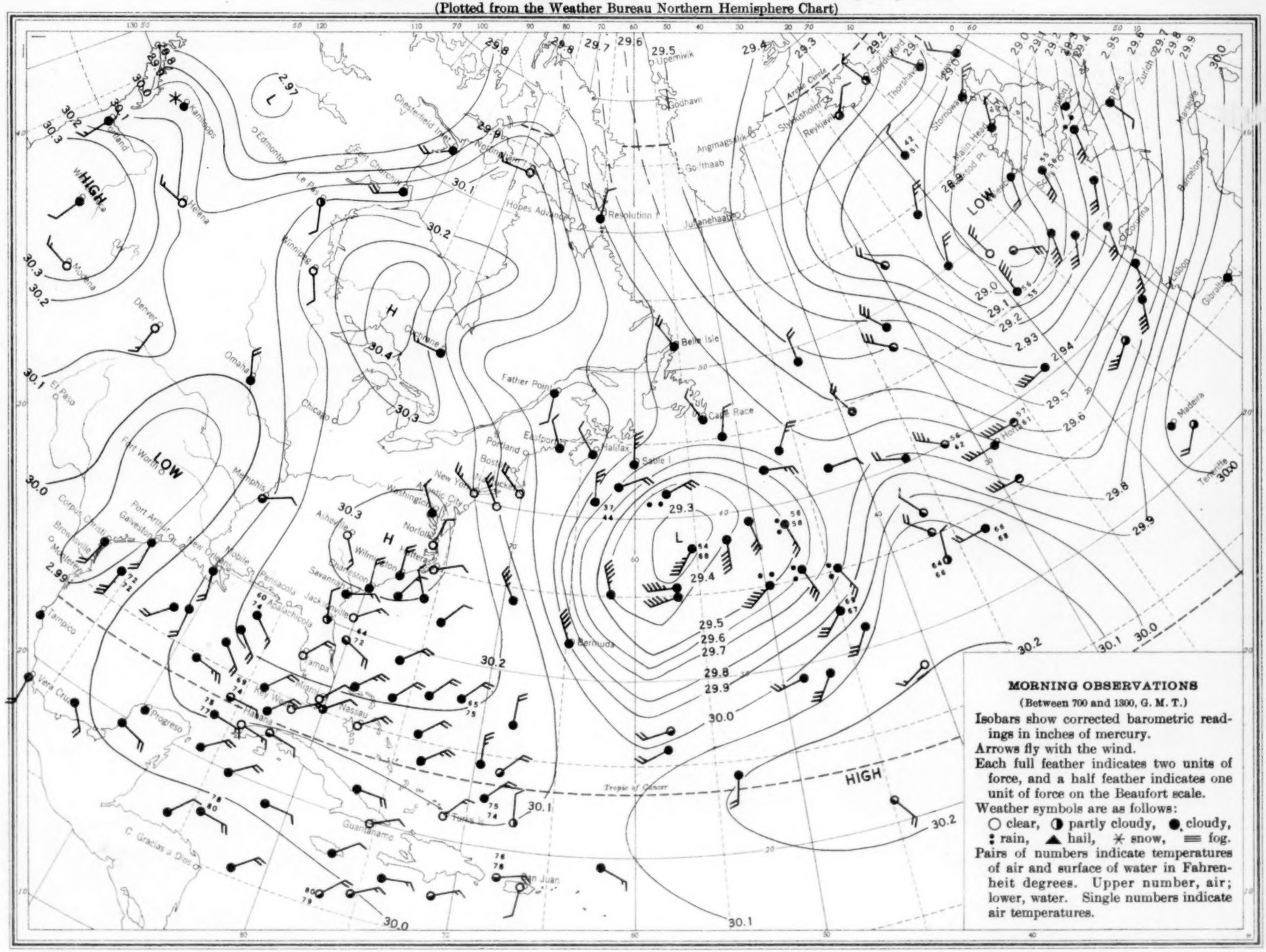


Chart XIII. Weather Map of North Atlantic Ocean, January 17, 1939

Chart XIII. Weather Map of North Atlantic Ocean, January 17, 1939

(Plotted from the Weather Bureau Northern Hemisphere Chart)



MORNING OBSERVATIONS

(Between 700 and 1300, G. M. T.)

Isobars show corrected barometric readings in inches of mercury.

Arrows fly with the wind.

Each full feather indicates two units of force, and a half feather indicates one unit of force on the Beaufort scale.

Weather symbols are as follows:

○ clear, ◑ partly cloudy, ● cloudy, ⁝ rain, ▲ hail, ✳ snow, ≡ fog.

Pairs of numbers indicate temperatures of air and surface of water in Fahrenheit degrees. Upper number, air; lower, water. Single numbers indicate air temperatures.

Chart XIV. Weather Map of North Atlantic Ocean, January 18, 1939

(Plotted from the Weather Bureau Northern Hemisphere Chart)

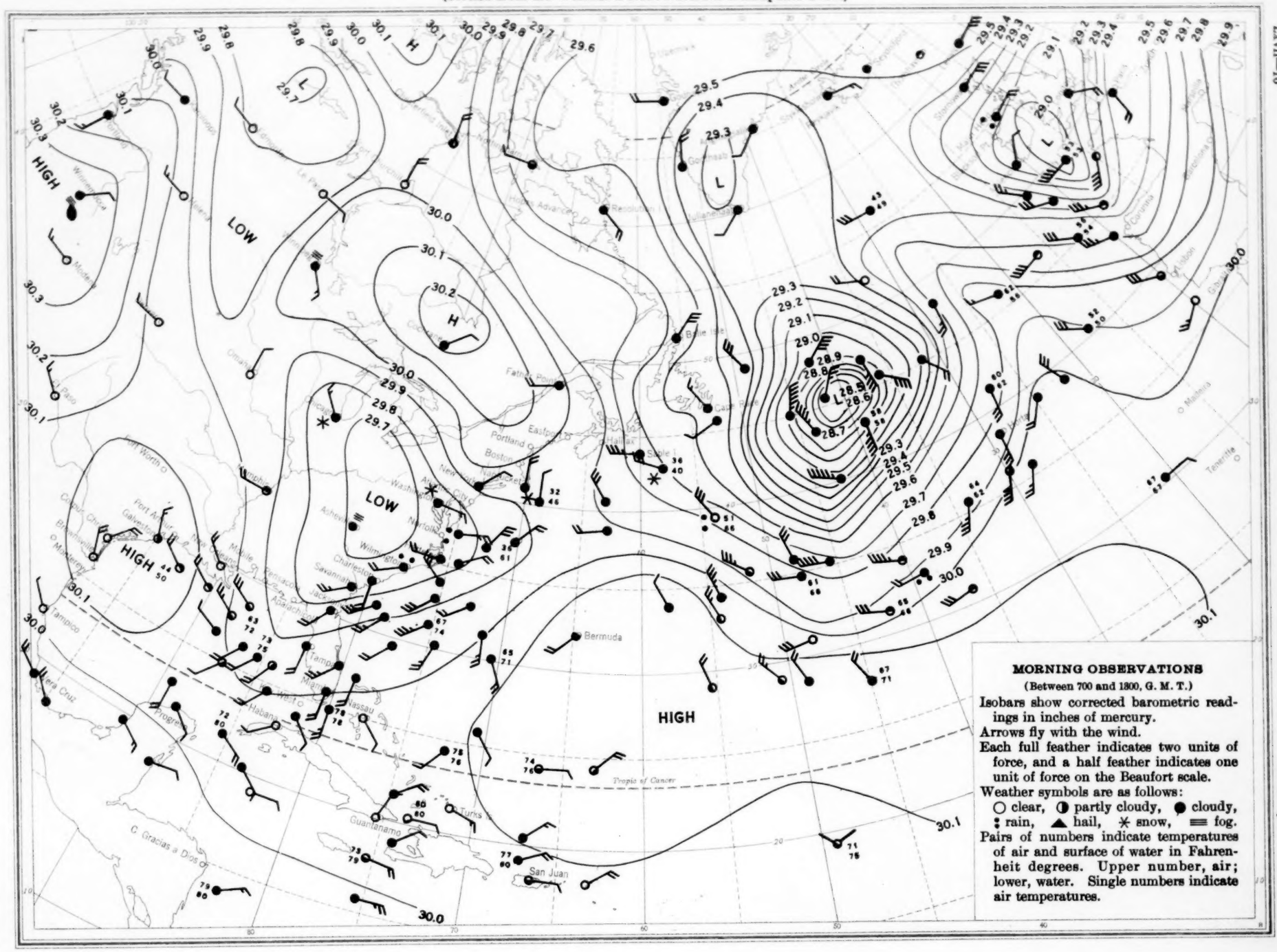

HIGH
LOW
LOW
HIGH
HIGH
Bermuda
Tropic of Cancer
San Juan
Habana
Tampico
Vera Cruz
Guantanamo
Turks
C Gracias a Dios
Tenerife
Madeira
MORNING OBSERVATIONS
(Between 700 and 1800, G. M. T.)
Isobars show corrected barometric readings in inches of mercury.
Arrows fly with the wind.
Each full feather indicates two units of force, and a half feather indicates one unit of force on the Beaufort scale.
Weather symbols are as follows:
○ clear, ◑ partly cloudy, ● cloudy, ⁝ rain, ▲ hail, ✳ snow, ≡ fog.
Pairs of numbers indicate temperatures of air and surface of water in Fahrenheit degrees. Upper number, air; lower, water. Single numbers indicate air temperatures.

Chart XV. Weather Map of North Atlantic Ocean, January 19, 1939

Chart XV. Weather Map of North Atlantic Ocean, January 19, 1939

(Plotted from the Weather Bureau Northern Hemisphere Chart)

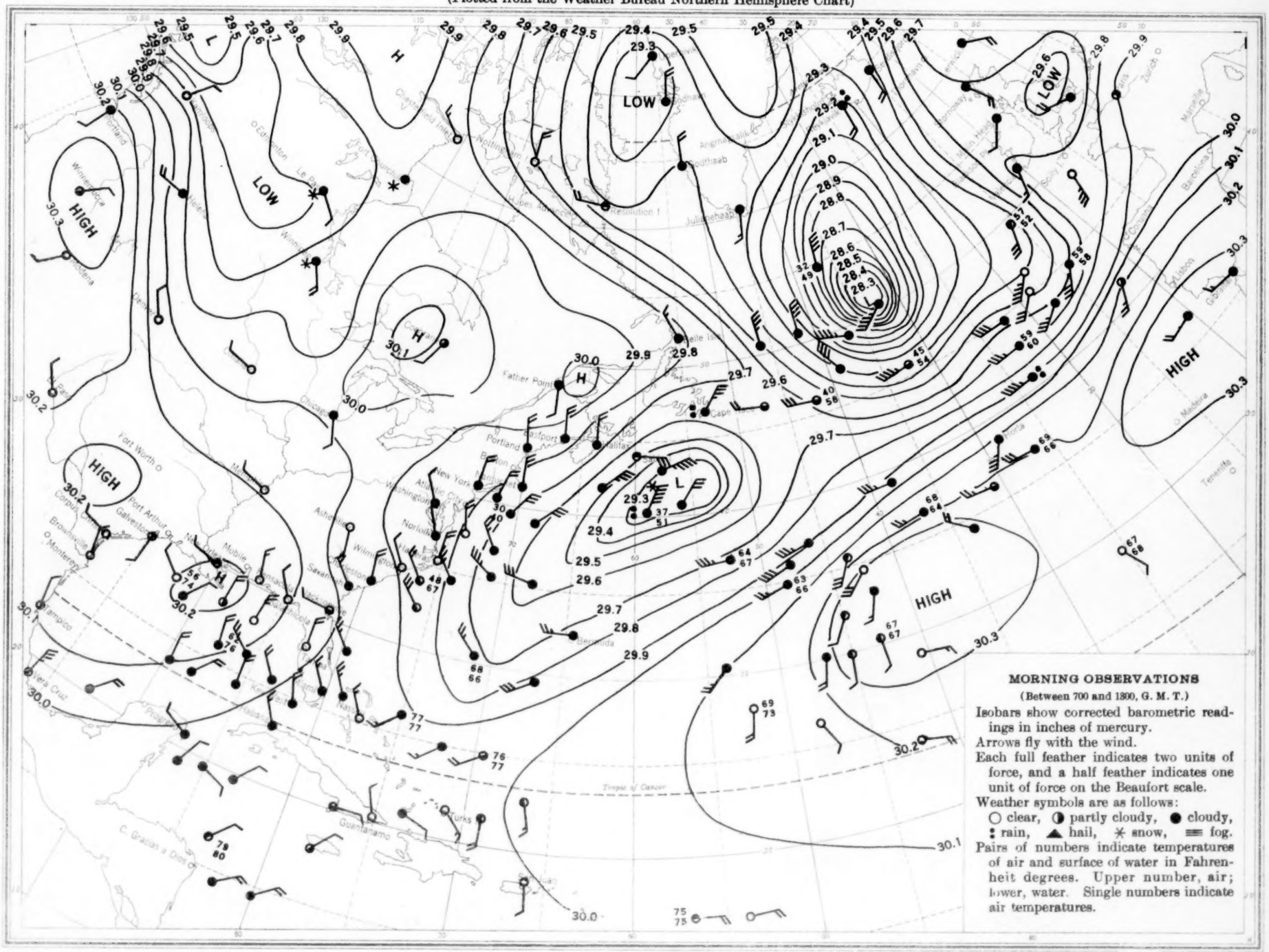
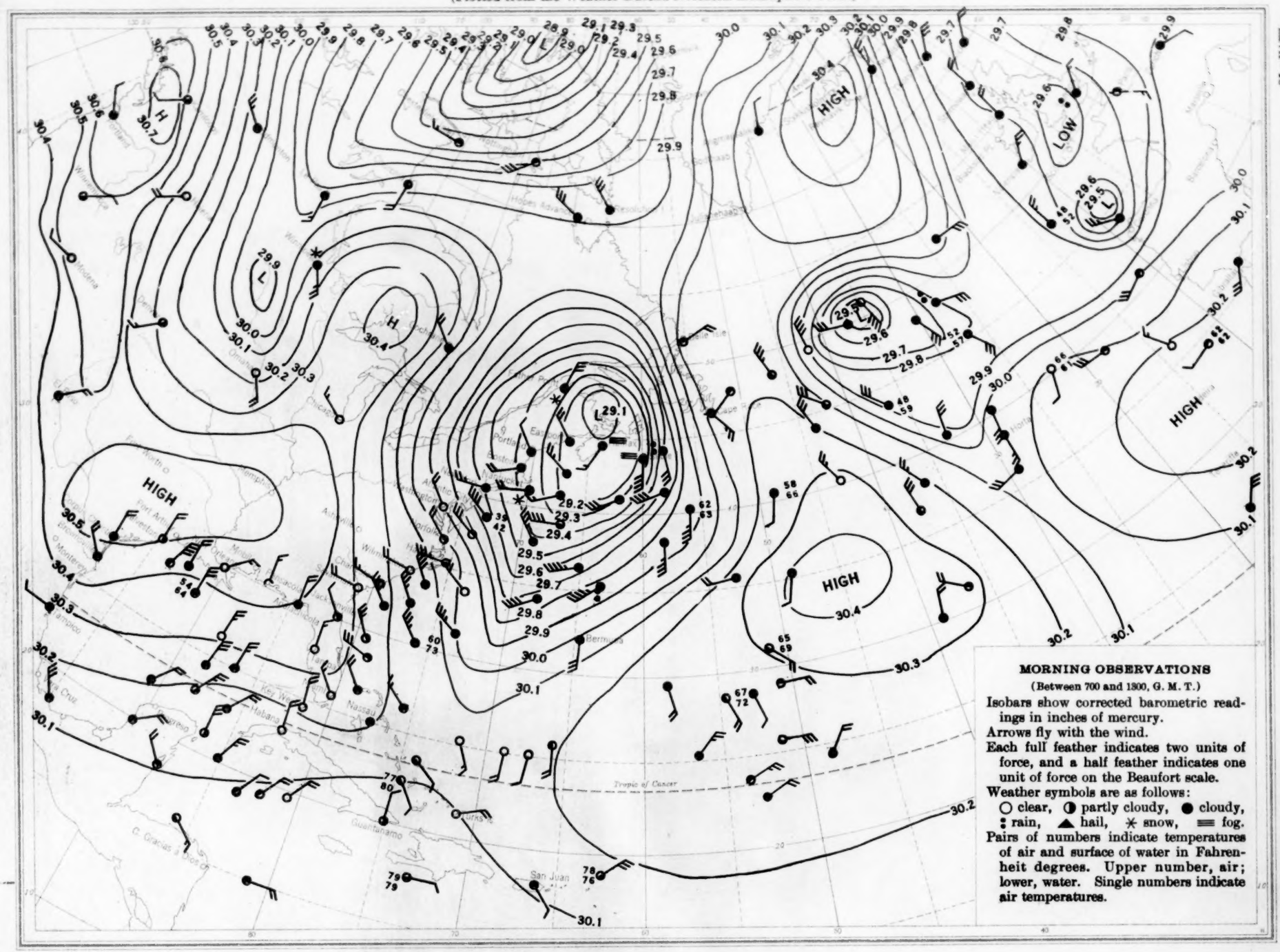

LOW
HIGH
LOW
HIGH
HIGH
LOW
HIGH
MORNING OBSERVATIONS
(Between 700 and 1800, G. M. T.)
Isobars show corrected barometric readings in inches of mercury.
Arrows fly with the wind.
Each full feather indicates two units of force, and a half feather indicates one unit of force on the Beaufort scale.
Weather symbols are as follows:
○ clear, ◑ partly cloudy, ● cloudy,
⁝ rain, ▲ hail, ✳ snow, ≡ fog.
Pairs of numbers indicate temperatures of air and surface of water in Fahrenheit degrees. Upper number, air; lower, water. Single numbers indicate air temperatures.

Chart XVI. Weather Map of North Atlantic Ocean, January 25, 1939

(Plotted from the Weather Bureau Northern Hemisphere Chart)